PB89-142491

Best Demonstrated Available Technology (BDAT) Background Document for K001

(U.S.) Environmental Protection Agency
Washington, DC

Aug 88

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/530-SW-88-0310	2.	3. Recipient's Accession No. PB89 142491/AS

4. Title and Subtitle
BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) BACKGROUND DOCUMENT FOR K001 (FINAL)

5. Report Date
AUGUST 1988

6.

7. Author(s)
JONES/BERLOW

8. Performing Organization Rept. No

9. Performing Organization Name and Address

U.S. EPA
OFFICE OF SOLID WASTE
401 M STREET, SW
WASHINGTON, DC 20460

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered
BACKGROUND DOCU: 8/88

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

→ The (background for EPA)

~~This~~ background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K001 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization information that serves as a basis for determining whether variances may be warranted. EPA may grant a variance in cases where the Agency determines that the waste in question is more difficult to treat than the waste upon which the treatment standards have been established.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement
RELEASE UNLIMITED

19. Security Class (This Report)
UNCLASSIFIED

21. No. of Pages
257

20. Security Class (This Page)
UNCLASSIFIED

22. Price
0

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)

EPA/530-SW-88-0310

PB89-142491

FINAL

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K001

James R. Berlow, Chief
Treatment Technology Section

Lisa Jones
Project Manager

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, D.C. 20460

August 1988

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

TABLE OF CONTENTS

Section Page

EXECUTIVE SUMMARY ix

1. INTRODUCTION 1-1

1.1 Legal Background 1-1
  1.1.1 Requirements Under HSWA 1-1
  1.1.2 Schedule for Developing Restrictions 1-4
1.2 Summary of Promulgated BDAT Methodology 1-5
  1.2.1 Waste Treatability Groups 1-7
  1.2.2 Demonstrated and Available Treatment Technologies 1-7
  1.2.3 Collection of Performance Data 1-11
  1.2.4 Hazardous Constituents Considered and Selected for Regulation 1-17
  1.2.5 Compliance with Performance Standards 1-30
  1.2.6 Identification of BDAT 1-32
  1.2.7 BDAT Treatment Standards for "Derived From" and "Mixed" Wastes 1-36
  1.2.8 Transfer of Treatment Standards 1-40
1.3 Variance from the BDAT Treatment Standard 1-41

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION 2-1

2.1 Industry Affected and Process Description 2-1
2.2 Waste Characterization 2-6

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES 3-1

3.1 Applicable Treatment Technologies 3-1
3.2 Demonstrated Treatment Technologies 3-3
  3.2.1 Incineration 3-5
  3.2.2 Fuel Substitution 3-24
  3.2.3 Chemical Precipitation 3-39
  3.2.4 Sludge Filtration 3-51
  3.2.5 Stabilization of Metals 3-55

4. PERFORMANCE DATA BASE 4-1

4.1 BDAT List Organics Treatment Data 4-1
4.2 BDAT List Metals Treatment Data 4-2
  4.2.1 Wastewater 4-2
  4.2.2 Nonwastewater 4-3

TABLE OF CONTENTS (Continued)

Section Page

5. IDENTIFICATION OF THE BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) FOR K001 5-1

5.1 BDAT for Treatment of Organic Constituents 5-1
5.2 BDAT for Treatment of Metal Constituents 5-3
  5.2.1 Wastewater 5-4
  5.2.2 Nonwastewater 5-5

6. SELECTION OF REGULATED CONSTITUENTS 6-1

6.1 Identification of BDAT List Constituents in Untreated K001 6-1
6.2 Determination of Significant Treatment from BDAT 6-2
  6.2.1 BDAT List Organic Constituents 6-2
  6.2.2 BDAT List Metal Constituents 6-2
6.3 Selection of Regulated Constituents 6-4
  6.3.1 BDAT List Organic Constituents 6-4
  6.3.2 BDAT List Metal Constituents 6-6

7. CALCULATION OF BDAT TREATMENT STANDARDS 7-1

7.1 Editing the Data 7-2
  7.1.1 BDAT List Organics Treatment 7-2
  7.1.2 BDAT List Metals Treatment 7-2
7.2 Correction of Analytical Data 7-4
  7.2.1 Correction of BDAT List Organics Data 7-4
  7.2.2 Correction of BDAT List Metals Data 7-5
7.3 Calculation of Variability Factors 7-6
7.4 Calculation of Treatment Standards 7-6

8. ACKNOWLEDGMENTS 8-1

9. REFERENCES 9-1

APPENDIX A STATISTICAL METHODS A-1

APPENDIX B ANALYTICAL METHODS AND QA/QC B-1

APPENDIX C CONCENTRATION/BOILING POINT/BOND DISSOCIATION ENERGY RANKING FOR BDAT LIST VOLATILES/SEMIVOLATILES IN K001 .... C-1

TABLE OF CONTENTS (Continued)

Section Page

APPENDIX D METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY D-1

APPENDIX E CALCULATIONS OF TREATMENT STANDARDS E-1

APPENDIX F DELETION OF PERFORMANCE DATA FOR F006 WASTES F-1

LIST OF TABLES

Table		Page
1-1	BDAT Constituent List	1-1
2-1	Number of Wood Preserving Facilities by State	2-2
2-2	Number of Wood Preserving Facilities by EPA Region	2-3
2-3	Major Constituent Composition - Untreated K001 Waste	2-7
2-4	BDAT List Constituent Composition	2-8
4-1	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 1	4-6
4-2	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 2	4-8
4-3	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 3	4-10
4-4	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 4	4-12
4-5	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 5	4-14
4-6	Rotary Kiln Incineration of K001 - Creosote Sample Set No. 6	4-16
4-7	Rotary Kiln Incineration of K001 - PCP Sample Set No. 7	4-18
4-8	Rotary Kiln Incineration of K001 - PCP Sample Set No. 8	4-20
4-9	Rotary Kiln Incineration of K001 - PCP Sample Set No. 9	4-22
4-10	Incinerator Operating Data for K001 - Creosote Sample Sets Number 1 and 2	4-24
4-11	Incinerator Operating Data for K001 - Creosote Sample Sets Number 3 and 4	4-25
4-12	Incinerator Operating Data for K001 - Creosote Sample Sets Number 5 and 6	4-26

LIST OF TABLES (Continued)

Table Page

4-13 Incinerator Operating Data for K001-PCP Sample Sets Numbers 7, 8 and 9 4-27

4-14 Performance Data for Chemical Precipitation and Filtration on Mixed Waste Sampled by EPA at Envirite Co. 4-28

4-15 Performance Data for Untreated and Treated F006 Wastes by Stabilization 4-31

5-1 Accuracy-Corrected Data for Untreated and Treated F006 Wastes by Stabilization 5-7

6-1 Status of BDAT List Constituent Presence in Untreated K001 6-8

6-2 BDAT List Constituents Detected in Untreated K001 - Creosote and Treatment Residuals 6-15

6-3 BDAT List Constituents Detected in Untreated K001 - PCP and Treatment Residuals 6-16

7-1 Corrected Values for BDAT List Organics 7-7

7-2 Corrected Values for K001 Nonwastewater Regulated Metal Constituents Treated by Stabilization 7-8

7-3 Corrected Values for K001 Wastewater Regulated Metal Constituents Treated by Chemical Precipitation and Filtration 7-9

7-4 Calculation of Treatment Standards for K001 7-10

A-1 95th Percentile Values for the F Distribution A-1

B-1 Analytical Methods for K001 Regulated Organic Constituents B-2

B-2 K001 - Matrix Spike Recoveries Used to Calculate Correction Factors for Regulated Organic Constituents B-3

B-3 K001 - Creosote Water Sample Volatile Organic Matrix Spike Recoveries B-4

LIST OF TABLES (Continued)

Table | Page

B-4 K001 - Creosote Ash Water Sample Volatile Organic Matrix Spike Recoveries B-5

B-5 K001 - Creosote Water Sample Semivolatile Organic Matrix Spike Recoveries B-6

B-6 K001 - Creosote Ash Sample Semivolatile Organic Matrix Spike Recoveries B-7

B-7 K001 - PCP Ash Sample Duplicate Matrix Spike Data - Volatile Organics B-8

B-8 K001- PCP TCLP Ash Sample Duplicate Matrix Spike Data - Volatile Organics B-9

B-9 K001 - Cresote PCP TCLP Ash Duplicate Matrix Spike Data - Semivolatile Organics B-10

B-10 K001 - Cresote PCP TCLP Ash Duplicate Matrix Spike Data - Volatile Organics B-11

B-11 K001 - PCP Scrubber Water Duplicate Matrix Spike Data - Semivolatile Organics B-12

B-12 Matrix Spike Recoveries for Stabilized F006 Nonwastewater Residuals B-13

B-13 Matrix Spike Recoveries for Metals in TCLP Extracts for K061 from Horsehead Resource Development Co. B-14

C-1 Concentration/Boiling Point/Bond Dissociation Energy Ranking for BDAT List Volatiles/Semivolatiles in K001 ..... C-2

F-1 Deletion of Stabilization Performance Data for F006 Wastes F-2

LIST OF FIGURES

Figure		Page
2-1	Wood Preserving Facilities by State and EPA Region	2-4
2-2	Wood Preserving Process	2-5
3-1	Liquid Injection Incinerator	3-9
3-2	Rotary Kiln Incinerator	3-10
3-3	Fluidized Bed Incinerator	3-12
3-4	Fixed Hearth Incinerator	3-13
3-5	Continuous Chemical Precipitation	3-43
3-6	Circular Clarifiers	3-45
3-7	Inclined Plate Settler	3-46
D-1	Schematic Diagram of the Comparative Method	D-2

EXECUTIVE SUMMARY

BDAT Treatment Standards for K001

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act as enacted by the Hazardous and Solid Waste Amendments on November 8, 1984, the Environmental Protection Agency (EPA) is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K001. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. These treatment standards become effective as of August 8, 1988.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K001 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization information that serves as a basis for determining whether variances may be warranted. EPA may grant a variance in cases where the Agency determines that the waste in question is more difficult to treat than the waste upon which the treatment standards have been established.

The introductory section, which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information--the number and locations of facilities affected by land disposal restrictions for K001 waste, the waste-generating process, waste characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

According to 40 CFR 261.32, waste code K001 is from the wood preserving industry and is listed as "bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol." The Agency has examined the sources of K001 generated from both the use of creosote-based preservatives and the use of pentachlorophenol-based preservatives and has determined that both types of wastes can be treated to the same concentrations when similar treatment technologies are applied.

EPA has estimated that over 400 facilities are potential generators of K001 waste. Generators of K001 generally fall under Standard Industrial Classification (SIC) Code 2491.

The Agency is regulating six organic and one inorganic constituent in both nonwastewater and wastewater forms of K001. (For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Wastes not meeting this definition must comply with the treatment standards for nonwastewaters.) The treatment standards for the organic constituents in both nonwastewater and wastewater are based on performance data from rotary kiln incineration. For the metal constituent, the treatment standard for wastewater is based on performance data from chemical precipitation followed by sludge filtration, while the treatment standards for nonwastewater are based on performance data from stabilization.

The following table presents the treatment standards for K001 nonwastewater and wastewater. For BDAT list organic constituents, treatment standards reflect the total constituent concentration. For the BDAT list metal constituent, the treatment standard in the nonwastewater reflects the concentration of the constituent in the leachate from the Toxicity Characteristic Leaching Procedure (TCLP) and the treatment standard in the wastewater reflects the total constituent concentration.

The units for the total constituent concentration are mg/kg (parts per million on a weight-by-weight basis) for the nonwastewater and mg/l (parts per million on a weight-by-volume basis) for the wastewater. The units for the leachate concentration are mg/l. Note that if the concentrations of the regulated constituents in the waste, as generated, are lower than or equal to the treatment standards, then treatment is not required prior to land disposal.

---

*The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by method 209C (Total Suspended Solids Dried at 103-105°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix B of this background document.

BDAT Treatment Standards for K001

Constituent	Maximum for any single grab sample		
	Nonwastewater		Wastewater
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
Volatile Organics			
Toluene	0.14	NA	0.14
Xylene (total)	0.16	NA	0.16
Semivolatile Organics			
Naphthalene	8.0	NA	0.15
Pentachlorophenol	37	NA	0.88
Phenanthrene	8.0	NA	0.15
Pyrene	7.3	NA	0.14
Metals			
Lead	NA	0.51	0.037

NA = Not applicable.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters. Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and

5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.

2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:

   - Number and types of constituents treated;
   - Performance (concentration of the constituents in the treatment residuals); and
   - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoro-ethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4 Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01 6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104-28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be present.

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.

3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.

2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.

3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.

4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards, then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the appropriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the requirements of 40 CFR Part 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.

2. A statement of the petitioner's interest in the proposed action.

3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.

4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.

5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)

6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)

7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.

8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.

10. A description of the methodologies and equipment used to obtain representative samples.

11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.

12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

This section discusses the industry affected by the land disposal restrictions for K001 waste, describes the process that generates the waste, and presents available waste characterization data.

According to 40 CFR Part 261.32, the waste identified as K001 is defined as the "bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol." The Agency has determined that K001 wastes generated from the use of creosote- and/or pentachlorophenol-based wood preservatives represent one treatability group.

2.1 Industry Affected and Process Description

The listed waste K001 is generated in the wood preserving industry. The Agency estimates that over 400 facilities have wood preserving processes that could potentially generate K001 waste. Table 2-1 lists the number of facilities by State, and Table 2-2 summarizes the number of facilities for each EPA Region. Figure 2-1 illustrates these data geographically on a map of the United States.

The preservation of wood using creosote and/or pentachlorophenol generates wastewaters containing hazardous constituents present in the preservatives. This process is illustrated in Figure 2-2. Creosote is a derivative of coal containing a wide range of constituents including cresols, phenol, 2,4-dimethylphenol, naphthalene, benz(a)anthracene, benzo(a)pyrene, fluoranthene, benzo(b)fluoranthene, chrysene, benzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, and acenaphthalene. The

Table 2-1 Number of Wood Preserving Facilities by State[a]

EPA State (Region)	Number of facilities	EPA State (Region)	Number of facilities
AL (IV)	29	MT (VIII)	
AK (X)		NE (VII)	
AZ (IX)		NV (IX)	
AR (VI)	17	NH (I)	
CA (IX)	31	NJ (II)	
CO (VIII)		NM (VI)	
CT (I)		NY (II)	
DE (III)		NC(IV)	29
DC (III)		ND (VIII)	
FL (IV)	25	OH (V)	11
GA (IV)	30	OK (VI)	
HI (IX)		OR (X)	12
ID (X)		PA (III)	16
IL (V)	11	RI (I)	
IN (V)	13	SC (IV)	11
IA (VII)		SD (VIII)	
KS (VII)		TN (IV)	7
KY (IV)	12	TX (VI)	33
LA (VI)	21	UT (VIII)	
ME (I)		VT (I)	
MD (III)		VA (III)	17
MA (I)		WA (X)	22
MI (V)		WV (III)	8
MN (V)	12	WI (V)	11
MS (IV)	27	WY (VIII)	
MO (VII)	22		

[a] Includes data for SIC code 2491 only.
Reference: U.S. Department of Commerce 1984.

Table 2-2 Number of Wood Preserving Facilities by EPA Region[a]

EPA Region	Number of facilities
I	-
II	-
III	41
IV	170
V	58
VI	81
VII	22
VIII	-
IX	31
X	34
TOTAL	437

[a] Includes data for SIC code 2491 only.
Reference: U.S. Department of Commerce 1984.

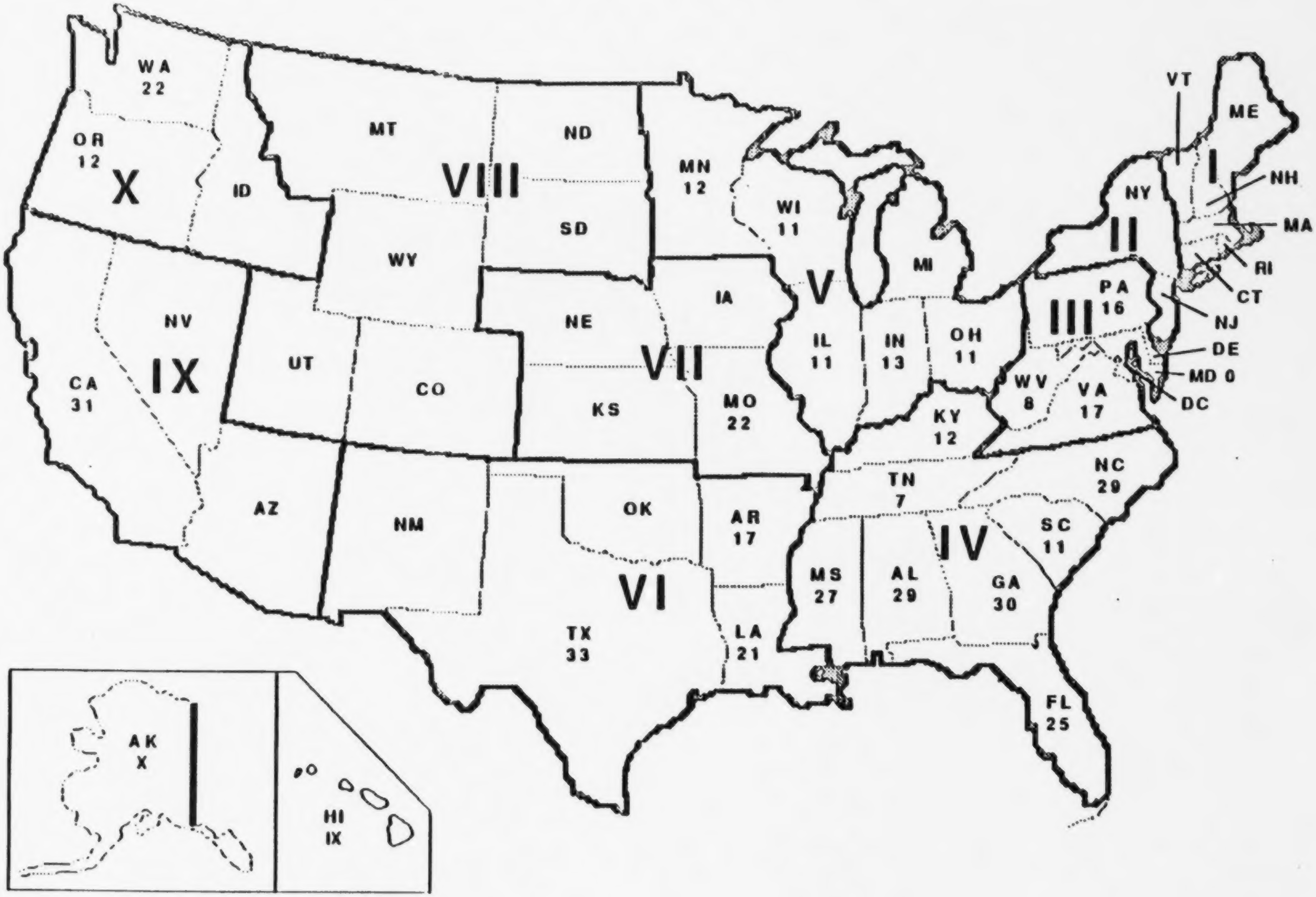

WA
22
OR
12
X
ID
MT
VIII
ND
SD
WY
MN
12
WI
11
MI
NY
II
VT
ME
I
NH
MA
RI
CT
NJ
DE
MD 0
DC
PA
16
III
CA
31
NV
IX
UT
CO
NE
KS
VII
IA
MO
22
IL
11
V
IN
13
OH
11
WV
8
VA
17
KY
12
AZ
NM
OK
TX
33
VI
AR
17
LA
21
TN
7
NC
29
SC
11
MS
27
AL
29
GA
30
IV
FL
25
AK
X
HI
IX

FIGURE 2-1 WOOD PRESERVING FACILITIES BY STATE AND EPA REGION

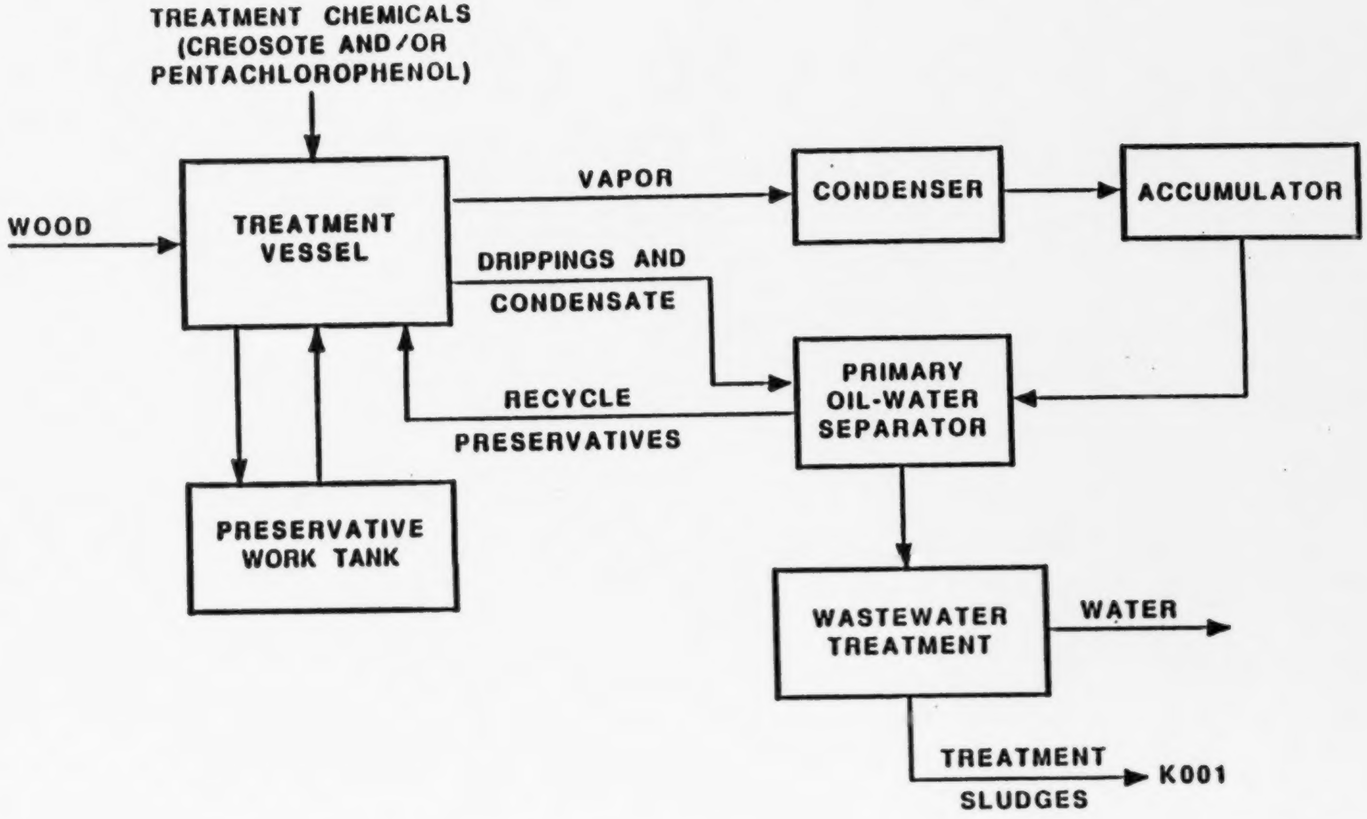

TREATMENT CHEMICALS (CREOSOTE AND/OR PENTACHLOROPHENOL)
WOOD
TREATMENT VESSEL
VAPOR
CONDENSER
ACCUMULATOR
DRIPPINGS AND CONDENSATE
PRIMARY OIL-WATER SEPARATOR
RECYCLE PRESERVATIVES
PRESERVATIVE WORK TANK
WASTEWATER TREATMENT
WATER
TREATMENT SLUDGES
K001

FIGURE 2-2 WOOD PRESERVING PROCESS

treatment by any means (including simple settling) of these wastewaters generates the listed waste K001.

The wood preserving process consists of two steps: (1) pretreatment of the wood to reduce its natural moisture content and (2) impregnation of the wood with preservatives including creosote and/or pentachlorophenol. These agents are added to wood to increase its resistance to natural decay, attack by insects, and microorganisms. Drippings and condensed vapors generated during preservation treatment are sent to the oil-water separator. In the oil-water separator, wood treatment chemicals are recovered and recycled back to the preserving process. The wastewater, contaminated with components of creosote, pentachlorophenol, and/or other related compounds, is pumped to wastewater treatment. The treatment residual generated is the listed waste K001.

2.2 Waste Characterization

This section includes all waste characterization data available to the Agency for untreated K001 waste. An estimate of the major constituents that compose the waste and their approximate concentrations is presented in Table 2-3. The percent concentration of each major constituent in the waste was determined by best estimates based on chemical analyses of K001 wastes from wood preservation using creosote- and pentachlorophenol-based treatment chemicals. The Agency has obtained compositional data from its own testing program and from numerous literature sources. The ranges of BDAT list constituents present in the wastes and other available data are presented in Table 2-4.

Table 2-3 Major Constituent Composition[a]

Untreated K001 Waste

Major constituents	Concentration (%)
Soil	35
BDAT list organic constituents	
Naphthalene	4.0
Phenanthrene	3.5
Fluoranthene	2.0
Acenaphthene	2.0
Pyrene	1.5
Fluorene	1.5
Anthracene	1.0
Pentachlorophenol	<1.0
Others	8.5
Water	20
Other organic compounds	14
Wood chips	5
BDAT list metals	<1
	100

---

[a] Percent concentrations presented here were determined from engineering judgment based on chemical analyses.

Table 2-4 BDAT List Constituent Composition

Constituent Source of data:	Untreated K001 waste total composition (ppm) (a)	(b)	(c)	(d)	(e)	(f)	(g)
Acenaphthene	-	3,000	-	-	-	15,000-21,000	13,000-18,000
Anthracene	8,410	-	-	-	-	7,300-15,000	8,500-13,000
Chrysene	-	45	9.29	4.5	2.1	4,100-4,800	<2,500-3,400
Fluoranthene	5,090	1,400	-	-	-	BDL	13,000-21,000
Naphthalene	43,640	1,200	-	-	-	29,000-43,000	26,000-43,000
Pyrene	604	52	-	-	-	12,000-17,000	9,200-15,000
Phenanthrene	8,410	3,200	-	-	-	28,000-42,000	28,000-43,000
Pentachlorophenol	1.84	-	4.8	302	58	BDL	920-3,000
2,4-dichlorophenol	1,650	-	-	-	-	BDL	BDL
p-chloro-m-cresol	1,690	-	-	-	-	BDL	BDL
2,4-dimethyl phenol	-	8.2	-	4.4	3.4	BDL	BDL
Benzo(g,h,i) perylene	-	84	-	-	-	BDL	BDL
Fluorene	-	1,400	-	-	-	12,000-18,000	8,200-12,000
Dibez(a,h) anthracene	-	-	0.052	-	-	BDL	BDL
Benz(a(anthracene	-	-	1.25	3.7	0.149	BDL	<2,500-3,400
Benzo(a) pyrene	-	-	5.98	-	-	BDL	<250-340
Phenol	-	-	4.5	9.0	16	2,400-3,900	BDL
2-Chlorophenol	-	-	0.30	39	1.2	BDL	BDL
2,4,6-trichlorophenol	-	-	-	-	25	BDL	BDL
Benzo(b and/or k)fluoranthrene	-	-	-	-	-	BDL	940-2,300

- = No data.

BDL = Below detection limit.

(a) Reference - USEPA 1980a.
(b) Reference - USEPA 1980a.
(c) Reference - Myers 1979.
(d) Reference - Myers 1979.
(e) Reference - Myers 1979.
(f) Reference - USEPA 1987a.
(g) Reference - USEPA 1987b.

Table 2-4 BDAT List Constituent Composition (continued)

	Untreated K001 waste total composition (ppm)							
Constituent Source of data:	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
Acenaphthene	-	-	-	-	-	-	-	-
Anthracene	-	-	-	-	-	-	-	-
Chrysene	-	-	-	1-170	-	-	-	-
Fluoranthene	-	-	-	-	-	-	-	-
Naphthalene	20,000	-	-	-	1.7-150	-	-	-
Pyrene	-	-	-	-	0.17-440	-	-	-
Phenanthrene	-	-	-	3.5-900	-	-	-	-
Pentachlorophenol	50,000-200,000	10,000	0.034	-	-	55-1,500	0.18-30	20,000-50,000
2,4-dichlorophenol	-		-	-	-	165	-	-
p-chloro-m-cresol	-	-	-	-	-	0.17	-	-
2,4-dimethyl phenol	-	-	-	-	-	-	-	-
Benzo(g,h,i) perylene	-	-	-	-	-	-	-	-
Fluorene	-	-	-	0.93-560	-	-	-	-
Dibez(a,h) anthracene	-	-	-	-	-	-	-	-
Benz(a) anthracene	-	-	-	0.014-0.37	1-260	-	-	-
Benzo(a) pyrene	-	-	-	-	-	-	-	-
Phenol	-	10,000	5.043	-	-	<5.0	0.45-1.6	-
2-Chlorophenol	-	-	-	-	-	-	0.12-39.6	-
2,4,6-trichlorophenol	-	-	-	-	-	2.5	-	-
2,4-Dinitrophenol	-	-	0.024	-	-	-	0.3-0.8	-
"Creosote"	-	-	10	-	-	-	-	-

- = No data.

BDL = Below detection limit.

(h) Reference - USEPA 1980a.
(i) Reference - DPRA 1984.
(j) Reference - Myers 1979.
(k) Reference - K.W. Brown 1981.
(l) Reference - Acurex 1982.
(m) Reference - Acurex 1982.
(n) Reference - Mitre 1981.
(o) Reference - Illinois EPA 1983.

These data display the range of concentrations of BDAT list organic constituents that may be present in K001 wastes. Such variations may be attributed to the type of preservative chemicals used and the type of wastewater treatment systems used. Generally, these K001 wastes contain numerous polynuclear aromatic compounds and chlorinated phenolics present in the wood preservatives. No characterization data identified in the literature for K001 had values for BDAT list metals. The BDAT list metals detected in samples of K001 waste collected by the Agency are presented in Section 4 of this document.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section identifies the applicable and demonstrated treatment technologies for K001 waste. Detailed discussions are provided for those technologies that have been demonstrated on a commercial basis.

3.1 Applicable Treatment Technologies

The Agency identified applicable treatment technologies based on available waste composition data, contacts with industry, and technical publications. The technologies considered to be applicable to untreated K001 waste are those that treat hazardous organic compounds by reducing their concentration. Additionally, residuals (wastewater and nonwastewater) generated from the treatment of BDAT list organics are expected to contain BDAT list metals in treatable concentrations. Treatment technologies applicable to reducing the concentration and/or leachability of metals in these residuals were also identified. The chemical composition of K001 waste most directly affects the technologies applicable to the waste. As shown in Section 2, the waste primarily contains high concentrations of BDAT list organic constituents, high suspended solids content, moderate water content, and BDAT list metals at concentrations below 1 percent.

For BDAT list organics, the Agency has identified treatment technologies that may be applicable to K001 because the technologies are designed to treat organic constituents in high suspended solids matrices. The technologies applicable to K001 are those that destroy or remove the organics present in the untreated waste.

The Agency has identified the following treatment technologies as applicable to BDAT list organic constituents in K001: incineration and fuel substitution. Incineration is a destruction technology that destroys organic constituents in wastes. Fuel substitution, like incineration, destroys the organic constituents of a waste but also derives a fuel value from the waste.

The Agency believes that solvent extraction may be applicable to K001 waste; however, EPA has not identified any facilities using solvent extraction on K001 or a similar waste. The Agency does not currently have sufficient information on waste parameters that affect treatment selection for solvent extraction to suggest that this technology is applicable for wastes similar to K001. Accordingly, EPA does not consider solvent extraction to be an applicable technology.

For the BDAT list metals present in the wastewater residual (i.e., scrubber water from incineration), the applicable treatment technologies are chemical precipitation followed by sludge filtration. Chemical precipitation removes dissolved metals from solution, and sludge filtration removes suspended solids that result from the use of an underdesigned clarifier or from the generation of precipitates that do not settle easily. The filter cake generated from sludge filtration (nonwastewater residual) contains BDAT list metals and requires treatment prior to land disposal.

For the BDAT list metals present in the nonwastewater residuals (wastewater treatment filter cake and ash), the applicable treatment technologies are high temperature metals recovery and stabilization. High temperature metals recovery provides for recovery of metals from wastes primarily by volatilization of metals and subsequent condensation and collection steps. The process yields a metal product for reuse and reduces the amount of waste that requires land disposal. Stabilization is designed to chemically and physically bind metal constituents of the waste into the microstructure of a cementitious matrix and thereby reduce their leaching potential. A variety of reagents, including portland cements, cement kiln dust, hydrated limes, quick lime, fly ash, and other pozzolanic materials, are used as binding reagents for various types of wastes containing metals.

3.2 Demonstrated Treatment Technologies

Of the two applicable technologies for BDAT list organic constituents, the Agency believes that rotary kiln incineration is demonstrated to treat K001 since it is currently being used to treat such wastes. The Agency has not identified any facilities using rotary kiln incineration for treatment of BDAT list organics in K001. However, rotary kiln incineration is a widely used full-scale treatment technology for wastes containing high concentrations of BDAT list organics in high filterable solid matrices. The goal of incineration is to thermally destroy (oxidize) the organic constituents of a waste. Typically, the types of incineration systems that are demonstrated on wastes include fluidized bed, rotary kiln, fixed hearth, and liquid injection. Rotary kiln incineration systems are designed specifically to handle sludges, solids, tarry wastes, and containerized liquids that are difficult to atomize through a liquid injector. Many rotary kiln incinerators are also designed to simultaneously incinerate other liquid wastes or supplemental fuel. The Agency believes that the performance of rotary kiln incineration adequately represents the performance achievable by other thermal destruction technologies (including fuel substitution) that are well designed and well operated, and can handle sludges of this type. Section 3.2.1 describes incineration technologies in more detail.

The Agency considers fuel substitution to be demonstrated on K001 because it is demonstrated on other wastes having similar parameters affecting treatment selection. Fuel substitution is described in greater detail in Section 3.2.2.

For K001 wastewaters, the Agency has not identified any facilities using chemical precipitation followed by sludge filtration on the scrubber water generated by incineration of K001. However, the Agency believes that chemical precipitation and sludge filtration are demonstrated for K001 wastes because they are demonstrated on similar wastewater streams containing BDAT list metals. Sections 3.2.3 and 3.2.4 describe chemical precipitation and sludge filtration.

The Agency has not identified any facilities using stabilization on the ash from incineration of K001 or the filter cake from treatment of K001 scrubber water. Stabilization is used on a full-scale basis to treat metals in nonwastewaters that have similar parameters affecting treatment selection. Thus, the Agency considers stabilization to be demonstrated for K001 ash and scrubber water precipitates.

The Agency does not believe that high temperature metals recovery is demonstrated on K001 nonwastewater residuals because it is not demonstrated specifically on K001 residuals or on other wastes having similar parameters affecting such treatment. EPA does not now have treatment performance data for high temperature metals recovery of K001 filter cake, incinerator ash, or other wastes having similar types and concentrations of BDAT list metal constituents. EPA will continue to investigate the application and demonstration of high temperature metals recovery for such treated residuals.

Detailed discussions of the demonstrated technologies including incineration, fuel substitution, chemical precipitation, filtration, and stabilization are presented below.

3.2.1 Incineration

This section addresses the commonly used incineration technologies--liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and, finally, important design and operating parameters. As appropriate, the subsections are divided by type of incineration unit.

(1) Applicability and use of incineration

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported, with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids, both of which can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that air emissions from incinerating some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than those currently used.

(2) Underlying principles of operation

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology is somewhat different than for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed incineration, the purpose of the primary chamber is not only to volatilize the waste but also to essentially combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of a fluidized bed incinerator than in that of a rotary kiln or fixed hearth incinerator because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of the incineration process

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber, where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat-resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

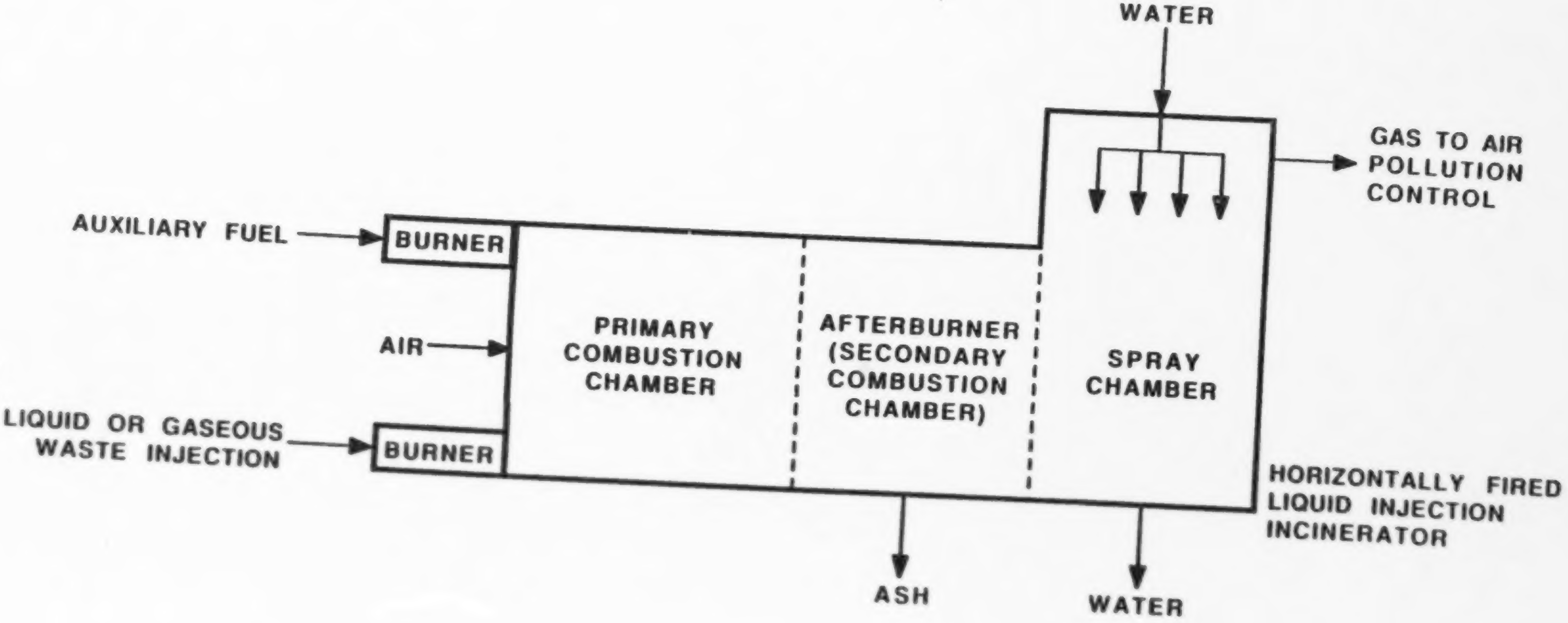

WATER
AUXILIARY FUEL
BURNER
GAS TO AIR POLLUTION CONTROL
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 3-1
LIQUID INJECTION INCINERATOR

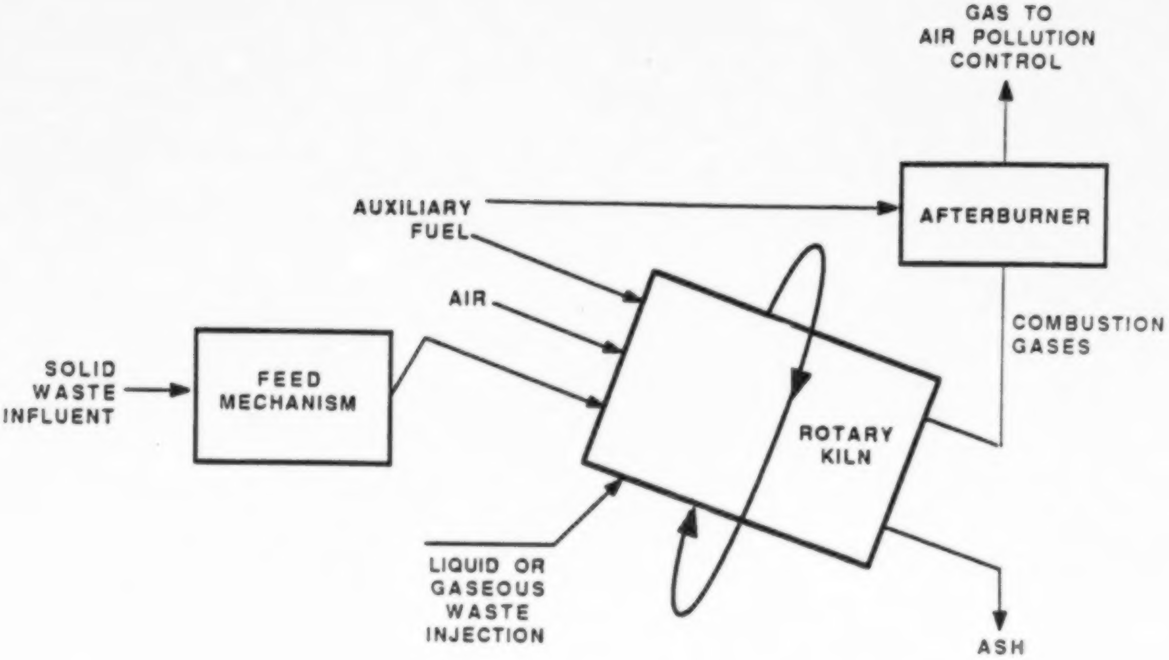

GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
AFTERBURNER
AIR
COMBUSTION GASES
SOLID WASTE INFLUENT
FEED MECHANISM
ROTARY KILN
LIQUID OR GASEOUS WASTE INJECTION
ASH

FIGURE 3-2
ROTARY KILN INCINERATOR

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone (see Figure 3-3).

(d) Fixed hearth. Fixed hearth incineration, also called controlled air or starved air incineration, is another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

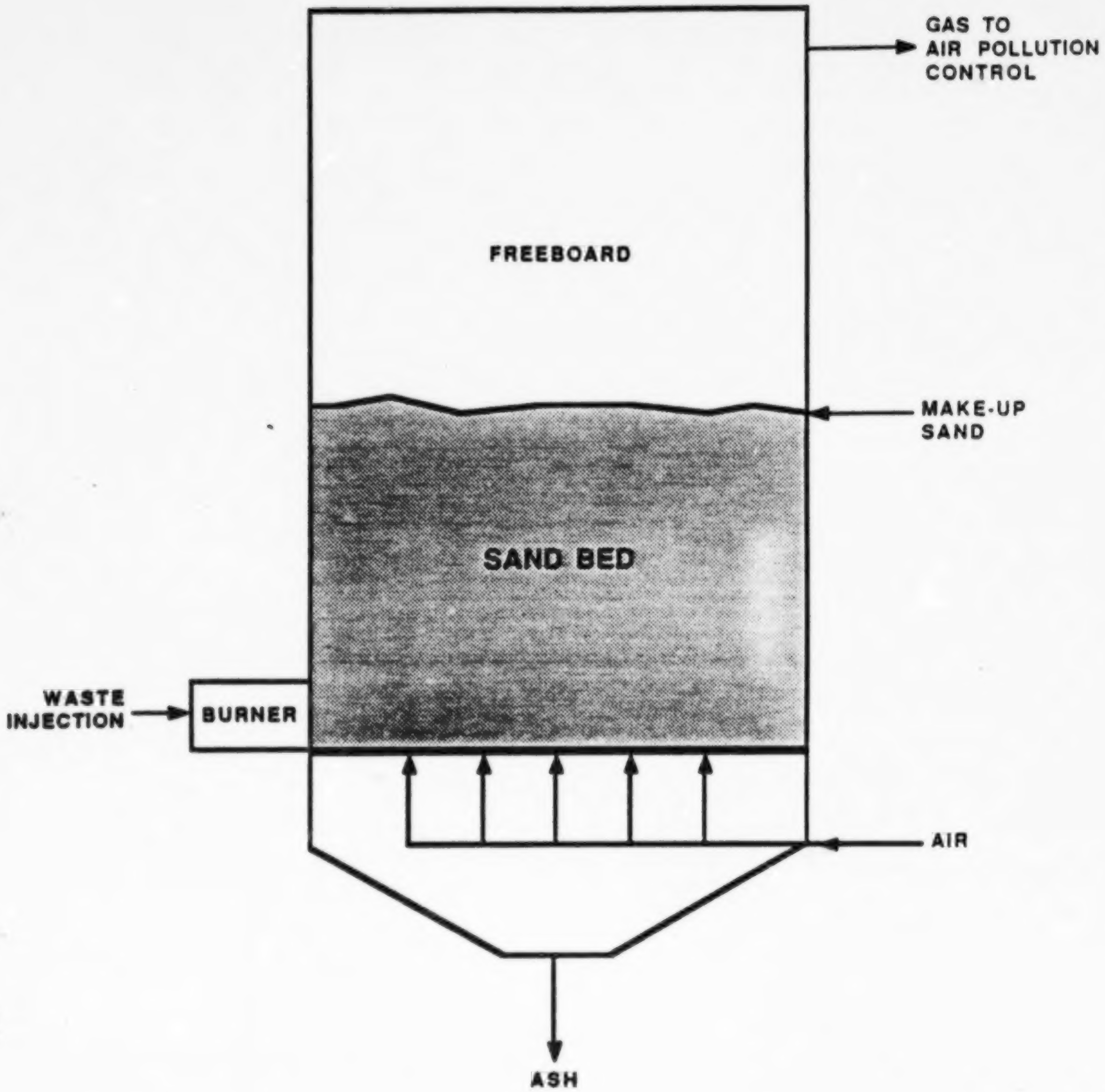

GAS TO
AIR POLLUTION
CONTROL
FREEBOARD
MAKE-UP
SAND
SAND BED
WASTE
INJECTION
BURNER
AIR
ASH

FIGURE 3-3
FLUIDIZED BED INCINERATOR

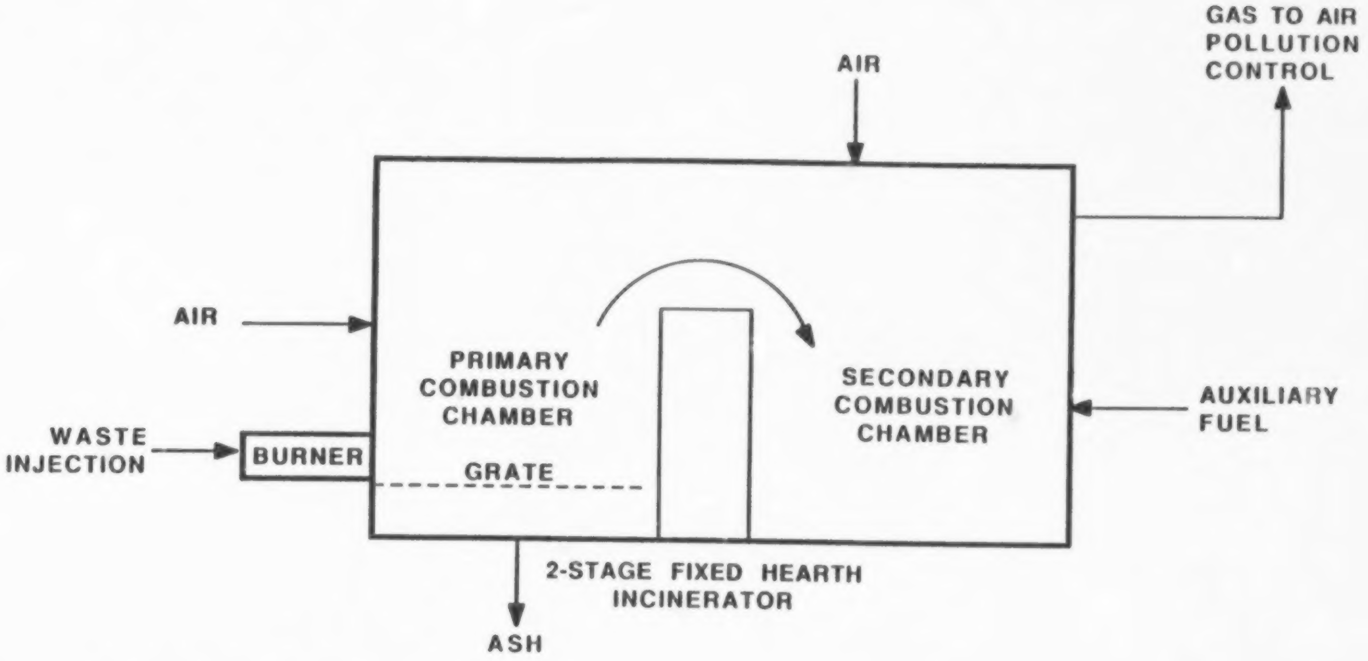

GAS TO AIR POLLUTION CONTROL
AIR
AIR
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
AUXILIARY FUEL
WASTE INJECTION
BURNER
GRATE
2-STAGE FIXED HEARTH INCINERATOR
ASH

FIGURE 3-4

FIXED HEARTH INCINERATOR

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove hydrochloric acid and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters of less than 1 micron and require high efficiency collection devices to minimize air emissions. In addition, scrubber systems provide additional buffer against accidental releases of incompletely destroyed waste products, which result from poor combustion efficiency or combustion upsets, such as flameouts.

(4) Waste characteristics affecting performance

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested wastes. This parameter is being used as a surrogate indicator of activation energy, which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case. Other energy effects (e.g., vibrational effects, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state. Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data was rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than of the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of the incinerator than of the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as how it can be measured, is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and is referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is described in Appendix D.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of the heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and the other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, removal of this constituent from the waste will depend on its volatility. As a surrogate of volatility, EPA is using boiling point of the constituent. Compounds with lower boiling points have higher vapor pressures and therefore would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Design and operating parameters

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are temperature, excess oxygen, and residence time. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposed restriction standards, EPA is concerned with these design parameters only when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned only with the waste characteristics that affect selection of the unit, not with the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, the more likely it is that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation that senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator at which the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. It is important that the incinerator contain oxygen in excess of the stoichiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location at which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, the volume of combustion gas can be calculated. After both the Btu content and the expected combustion gas volume have been determined, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit was operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether it is likely that sufficient energy will be provided to the waste to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature is important, in that it provides an indirect measure of the energy input (i.e., BTU/hr) available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln, including the length and diameter of the kiln, the waste feed rate, and the rate of rotation.

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as the RPM value increases, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously in the section on "Underlying principles of operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas (if halogens are present). The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were discussed under rotary kiln and will not be discussed here. The latter, bed pressure differential, is important in that it provides an indication of the amount of turbulence and therefore indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase. The pressure drop through the bed should be continuously monitored and recorded to ensure that the designed valued is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln with the exception that rate of rotation (i.e., RPM) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under "Rotary kiln"; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those previously discussed under "Liquid injection."

3.2.2 Fuel Substitution

Fuel substitution involves using hazardous waste as a fuel in industrial furnaces or in boilers for generation of steam. The hazardous waste may be blended with other nonhazardous wastes (e.g., municipal sludge) and/or fossil fuels.

(1) Applicability and use of fuel substitution. Fuel substitution has been used with industrial waste solvents, refinery wastes, synthetic fibers/petrochemical wastes, and waste oils. It can also be used when combusting other waste types produced during the manufacture of pharmaceuticals, pulp and paper, and pesticides. These wastes can be handled in a solid, liquid, or gaseous form.

The most common types of units in which waste fuels are burned are industrial furnaces and industrial boilers. Industrial furnaces include a diverse variety of industrial processes that produce heat and/or products by burning fuels. They include blast furnaces, smelters, and coke ovens. Industrial boilers are units wherein fuel is used to produce steam for process and plant use. Industrial boilers typically use coal, oil, or gas as the primary fuel source.

A number of parameters affect the selection of fuel substitution:

- Halogen content of the waste;
- Inorganic solids content (ash content) of the waste, particularly heavy metals;
- Heating value of the waste;
- Viscosity of the waste (for liquids);
- Filterable solids concentration (for liquids); and
- Sulfur content.

If halogenated organics are burned, halogenated acids and free halogen are among the products of combustion. These released corrosive gases may require subsequent treatment prior to venting to the atmosphere. Also, halogens and halogenated acids formed during combustion are likely to severely corrode boiler tubes and other process equipment. For this reason, halogenated wastes are blended into fuels only at very low concentrations to minimize such problems. High chlorine content can also lead to the incidental production (at very low concentrations) of other hazardous compounds such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), (polychlorinated dibenzofurans (PCDFs), and chlorinated phenols.

High inorganic solids content (i.e., ash content) of wastes may cause two problems: (1) scaling in the boiler and (2) particulate air emissions. Scaling results from deposition of inorganic solids on the walls of the boiler. Particulate emissions are produced by noncombustible inorganic constituents that flow out of the boiler with the gaseous combustion products. Because of these problems, wastes with significant concentrations of inorganic materials are not usually handled in boilers unless they have an air pollution control system.

Industrial furnaces vary in their tolerance to inorganic constituents. Heavy metal concentrations, found in both halogenated and nonhalogenated wastes used as fuel, can cause environmental concern because they may be emitted either in the gaseous emissions from the combustion process, in the ash residues, or in any produced solids. The partitioning of the heavy metals to these residual streams primarily depends on the volatility of the metal, waste matrix, and furnace design.

The heating value of the waste must be sufficiently high (either alone or in combination with other fuels) to maintain combustion temperatures consistent with efficient waste destruction and operation of the boiler or furnace. For many applications, only supplemental fuels having minimum heating values of 4,400 to 5,600 kcal/kg (8,000 to 10,000 BTU/lb) are considered to be feasible. Below this value, the unblended fuel would not be likely to maintain a stable flame, and its combustion would release insufficient energy to provide needed steam generation potential in the boiler or the necessary heat for an industrial furnace.

Some wastes with heating values of less than 4,400 kcal/kg (8,000 Btu/lb) can be used if sufficient auxiliary fuel is employed to support combustion or if special designs are incorporated into the combustion device. Occasionally, for wastes with heating values higher than virgin fuels, blending with auxiliary fuel may be required to prevent overheating or overcharging the combustion device.

In combustion devices designed to burn liquid fuels, the viscosity of liquid waste must be low enough that the liquid can be atomized in the combustion chamber. If viscosity is too high, heating of storage tanks may be required prior to combustion. For atomization of liquids, a viscosity of 165 centistokes (750 Saybolt Seconds Universal (SSU)) or less is typically required.

Filterable material suspended in the liquid fuel may prevent or hinder pumping or atomization.

Sulfur content in the waste may prevent burning of the waste because of potential atmospheric emissions of sulfur oxides. For instance, there are proposed Federal sulfur oxide emission regulations for certain new source industrial boilers (51 FR 22385). Air pollution control devices are available to remove sulfur oxides from the stack gases.

(2) Underlying principles of operation. For a boiler and most industrial furnaces there are two distinct principles of operation. Initially, energy in the form of heat is transferred to the waste to achieve volatilization of the various waste constituents. For liquids, volatilization energy may also be supplied by using pressurized

atomization. The energy used to pressurize the liquid waste allows the atomized waste to break into smaller particles, thus enhancing its rate of volatilization. The volatilized constituents then require additional energy to destabilize the chemical bonds and allow the constituents to react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the chemical bonds is referred to as the energy of activation.

(3) Description of the fuel substitution process. As stated, a number of industrial applications can use fuel substitution. Therefore, there is no one process description that will fit all of these applications. However, the following section provides a general description of industrial kilns (one form of industrial furnace) and industrial boilers.

(a) Kilns. Combustible wastes have the potential to be used as fuel in kilns and, for waste liquids, are often used with oil to co-fire kilns. Coal-fired kilns are capable of handling some solid wastes. In the case of cement kilns, there are usually no residuals requiring land disposal since any ash formed becomes part of the product or is removed by particulate collection systems and recycled back to the kiln. The only residuals may be low levels of unburned gases escaping with combustion products. If this is the case, air pollution control devices may be required.

Three types of kilns are particularly applicable: cement kilns, lime kilns, and lightweight aggregate kilns.

(i) Cement kilns. The cement kiln is a rotary furnace, which is a refractory-lined steel shell used to calcine a mixture of calcium, silicon, aluminum, iron, and magnesium-containing minerals. The kiln is normally fired by coal or oil. Liquid and solid combustible wastes may then serve as auxiliary fuel. Temperatures within the kiln are typically between 1,380 and 1,540°C (2,500 to 2,800°F). To date, only liquid hazardous wastes have been burned in cement kilns.

Most cement kilns have a dry particulate collection device (i.e., either an electrostatic precipitator or baghouse) with the collected fly ash recycled back to the kiln. Buildup of metals or other noncombustibles is prevented through their incorporation in the product cement. Since many types of cement require a source of chloride, most halogenated liquid hazardous wastes currently can be burned in cement kilns. Available information shows that scrubbers are not used.

(ii) Lime kilns. Quick-lime (CaO) is manufactured in a calcination process using limestone ($CaCO_3$) or dolomite ($CaCO_3$ and $MgCO_3$). These raw materials are also heated in a refractory-lined rotary kiln, typically to temperatures of 980 to 1,260°C (1,800 to 2,300°F). Lime kilns are less likely to burn hazardous wastes than cement kilns because product lime is often added to potable water systems. Only one lime kiln currently burns hazardous waste in the U.S. That particular facility sells its product lime for use as flux or as refractory in blast furnaces.

As with cement kilns, any collected fly ash is recycled back to the lime kiln, resulting in no residual streams from the kiln. Available information shows that scrubbers are not used.

(iii) Lightweight aggregate kilns. Lightweight aggregate kilns heat clay to produce an expanded lightweight inorganic material used in portland cement formulations and other applications. The kiln has a normal temperature range of 1,100 to 1,150°C (2,000 to 2,100°F). Lightweight aggregate kilns are less amenable to combustion of hazardous wastes as fuels than the other kilns described above because of lack of material in the kiln to adsorb halogens. As a result, burning of halogenated organics in these kilns would likely require afterburners to ensure complete destruction of the halogenated organics and scrubbers to control acid gas production. Such controls would produce a wastewater residual stream subject to treatment standards.

(b) Industrial boilers. A boiler is a closed vessel in which water is transformed into steam by the application of heat. Normally, heat is supplied by the combustion of pulverized coal, fuel oil, or gas. These fuels are fired into a combustion chamber with nozzles and burners that provide mixing with air. Liquid wastes, and granulated solid wastes in the case of grate-fired boilers, can be burned as auxiliary fuel in a boiler. Few grate-fired boilers burn hazardous wastes, however. For liquid-fired boilers, residuals requiring land disposal are generated only when the boiler is shut down and cleaned, which is generally done once or twice per year. Other residuals from liquid-fired boilers would be the gas emission stream, which would consist of any products of incomplete combustion, along with the normal combustion products. For example, chlorinated wastes would produce acid gases. If this is the case, air pollution control devices may be required. For solid-fired boilers, an ash normally is generated. This ash may contain residual amounts of organics from the blended waste/fuels as well as noncombustible materials. Land disposal of this ash would require compliance with applicable BDAT treatment standards.

(4) Waste characteristics affecting performance. For cement kilns and lime kilns and for lightweight aggregate kilns burning nonhalogenated wastes (i.e., no scrubber is needed to control acid gases), no residual waste streams would be produced. Any noncombustible material in the waste would leave the kiln in the product stream. As a result, in transferring standards EPA would not examine waste characteristics affecting performance but rather would determine the applicability of fuel substitution. That is, EPA would investigate the parameters affecting treatment selection. As mentioned previously, for kilns these parameters are Btu content, percent filterable solids, halogenated organics content, viscosity, and sulfur content.

Lightweight aggregate kilns burning halogenated organics and boilers burning wastes containing any noncombustibles will produce residual streams subject to treatment standards. In determining whether fuel substitution is likely to achieve the same level of performance on an untreated waste as on a previously treated waste, EPA will examine:

(1) relative volatility of the waste constituents, (2) the heat transfer characteristics (for solids); and (3) the activation energy for combustion.

(a) Relative volatility. The term relative volatility (α) refers to the ease with which a substance present in a solid or liquid waste will vaporize from that waste upon application of heat from an external source. Hence, it bears a relationship to the equilibrium vapor pressure of the substance.

EPA recognizes that the relative volatilities cannot be measured or calculated directly for the types of wastes generally treated in an industrial boiler or furnace. The Agency believes that the best measure of relative volatility is the boiling point of the various hazardous constituents and will, therefore, use this parameter in assessing volatility of the organic constituents.

(b) Heat transfer characteristics. Consistent with the underlying principles of combustion in aggregate kilns or boilers, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of industrial boilers burning solid fuels, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given boiler it can be assumed that the type of waste will have a minimal impact on the heat transferred from radiation. With regard to convection, EPA believes that the range of wastes treated would exhibit similar properties with regard to the amount of heat transferred by convection.

Therefore, EPA will not evaluate radiation convection heat transfer properties of wastes in determining similar treatability. For solids, the third heat transfer mechanism, conductivity, is the one principally operative or most likely to change between wastes. The method that EPA believes can be used to determine thermal conductivity of a nonwastewater can be found in Appendix D.

Using thermal conductivity measurements as part of a treatability comparison for two different wastes through a given boiler or furnace is most meaningful when applied to wastes that are homogeneous. As wastes exhibit greater degrees of nonhomogeneity, thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance and not heat flow through all parts of the waste). Nevertheless, EPA has not identified a better alternative to thermal conductivity, even for wastes that are nonhomogeneous.

Other parameters considered for predicting heat transfer characteristics were Btu value, specific heat, and ash content. These parameters can neither better account for nonhomogeneity nor better predict heat transferability through the waste.

(c) Activation energy. Given an excess of oxygen, an organic waste in an industrial furnace or boiler would be expected to convert to carbon dioxide and water, provided that the activation energy is achieved. Activation energy is the quantity of heat (energy) needed to destabilize molecular bonds and create reactive intermediates so that the oxidation (combustion) reaction will proceed to completion. As a measure of activation energy, EPA is using bond dissociation energies. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case.

In some instances, bond energies will not be available and will have to be estimated, or other energy effects (e.g., vibrational) and other reactions will have a significant influence on activation energy. Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters included heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction). Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of available kinetic data was rejected because while such data could be used to calculate some free energy values (ΔG), they could not be used for the wide range of hazardous constituents. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct comparison.

(5) Design and operating parameters

(a) Design parameters. Cement kilns and lime kilns, along with aggregate kilns burning nonhalogenated wastes produce no residual streams. Their design and operation is such that any wastes that are incompletely destroyed will be contained in the product. As a result, the Agency will not look at design and operating values for such devices since treatment, per se, cannot be measured through detection of constituents in residual streams. In this instance, it is important merely to ensure that the waste is appropriate for combustion in the kilns and that the kiln is operated in a manner that will produce a usable product.

Specifically, cement, lime, and aggregate kilns are demonstrated only on liquid hazardous wastes. Such wastes must be sufficiently free of filterable solids to avoid plugging the burners at the hot end of the kiln. Viscosity also must be low enough to inject the waste into the kiln through the burners. The sulfur content is not a concern unless the concentration in the waste is high enough to exceed Federal, State, or local air pollution standards promulgated for industrial boilers.

The design parameters which normally affect the operation of an industrial boiler (and aggregate kilns with residual streams) with respect to hazardous waste treatment are (1) the design temperature,

(2) the design retention time of the waste in the combustion chamber, and (3) turbulence in the combustion chamber. Evaluation of these parameters would be important in determining if an industrial boiler or industrial furnace is adequately designed for effective treatment of hazardous wastes. The rationale for selection of these three parameters is given below.

(i) Design temperature. Industrial boilers are generally designed based on their steam generation potential (Btu output). This factor is related to the design combustion temperature, which in turn depends on the amount of fuel burned and its Btu value. The fuel feed rates and combustion temperatures of industrial boilers are generally fixed based on the Btu values of fuels normally handled (e.g., No. 2 versus No. 6 fuel oils). When wastes are to be blended with fossil fuels for combustion, the blending, based on Btu values, must be such that the resulting Btu value of the mixture is close to that of the fuel value used in design of the boiler. Industrial furnaces also are designed to operate at specific ranges of temperature in order to produce the desired product (e.g., lightweight aggregate). The blended waste/fuel mixture should be capable of maintaining the design temperature range.

(ii) Design retention time. A sufficient retention time of combustion products is normally necessary to ensure that the hazardous substances being combusted (or formed during combustion) are completely oxidized. Retention times on the order of a few seconds are normally needed at normal operating conditions. For industrial furnaces, as well as boilers, the retention time is a function of the size of the furnace and the fuel feed rates. For most boilers and furnaces, the retention time usually exceeds a few seconds.

(iii) Turbulence. Boilers are designed so that fuel and air are intimately mixed. This helps ensure that complete combustion takes place. The shape of the boiler and the method of fuel and air feed influence the turbulence required for good mixing. Industrial furnaces also are designed for turbulent mixing where fuel and air are mixed.

(b) Operating parameters. The operating parameters that normally affect the performance of an industrial boiler and many industrial furnaces with respect to treatment of hazardous wastes are (1) air flow rate, (2) fuel feed rate, (3) steam pressure or rate of production, and (4) temperature. EPA believes that these four parameters will be used to determine if an industrial boiler burning blended fuels containing hazardous waste constituents is properly operated. The rationale for selection of these four operating parameters is given below. Most industrial furnaces will monitor similar parameters, but some exceptions are noted below.

(i) Air feed rate. An important operating parameter in boilers and many industrial furnaces is the oxygen content in the flue gas, which is a function of the air feed rate. Stable combustion of a fuel generally occurs within a specific range of air-to-fuel ratios. An oxygen analyzer in the combustion gases can be used to control the feed ratio of air to fuel to ensure complete thermal destruction of the waste and efficient operation of the boiler. When necessary, the air flow rate can be increased or decreased to maintain proper fuel-to-oxygen ratios. Some industrial furnaces do not completely combust fuels (e.g., coke ovens and blast furnaces); therefore, oxygen concentration in the flue gas is a meaningless variable.

(ii) Fuel feed rate. The rate at which fuel is injected into the boiler or industrial furnace will determine the thermal output of the system per unit of time (Btu/hr). If steam is produced, steam pressure monitoring will indirectly determine if the fuel feed rate is adequate. However, various velocity and mass measurement devices can be used to monitor fuel flow directly.

(iii) Steam pressure or rate of production. Steam pressure in boilers provides a direct measure of the thermal output of the system and is directly monitored by use of in-system pressure gauges. Increases or decreases in steam pressure can be effected by increasing or decreasing the fuel and air feed rates within certain operating design limits. Most industrial furnaces do not produce steam, but instead produce a product (e.g., cement, aggregate) and monitor the rate of production.

(iv) Temperature. Temperatures are monitored and controlled in industrial boilers to ensure the quality and flow rate of steam. Therefore, complex monitoring systems are frequently installed in the combustion unit to provide a direct reading of temperature. The efficiency of combustion in industrial boilers is dependent on combustion temperatures. Temperature may be adjusted to design settings by increasing or decreasing air and fuel feed rate.

Wastes should not be added to primary fuels until the boiler temperature reaches the minimum needed for destruction of the wastes. Temperature instrumentation and control should be designed to stop waste addition in the event of process upsets.

Monitoring and control of temperature in industrial furnaces are also critical to the product quality. For example, lime, cement, or aggregate kilns require minimum operating temperatures. Kilns have very high thermal inertia in the refractory and in-process product, high residence times, and high air flow rates, so that even in the case of a momentary stoppage of fuel flow to the kiln, organic constituents are likely to continue to be destroyed. The main operational control required for wastes burned in kilns is to stop waste flow in the event of low kiln temperature, loss of electrical power to the combustion air fan, and loss of primary fuel flow.

(v) Other operating parameters. In addition to the four operating parameters discussed above, EPA considered and then discarded one additional parameter--fuel-to-waste blending ratios. While the blending is done to yield a uniform Btu content fuel, blending ratios will vary on a wide range dependent on the Btu content of the wastes and fuels being used.

3.2.3 Chemical Precipitation

(1) Applicability and use of chemical precipitation. Chemical precipitation is used when dissolved metals are to be removed from solution. This technology can be applied to a wide range of wastewaters

containing dissolved BDAT list metals and other metals as well. This treatment process has been practiced widely by industrial facilities since the 1940s.

(2) Underlying principles of operation. The underlying principle of chemical precipitation is that metals in wastewater are removed by the addition of a treatment chemical that converts the dissolved metal to a metal precipitate. This precipitate is less soluble than the original metal compound and therefore settles out of solution, leaving a lower concentration of the metal present in the solution. The principal chemicals used to convert soluble metal compounds to the less soluble forms include lime ($Ca(OH)_2$), caustic (NaOH), sodium sulfide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulfide (FeS).

The solubility of a particular compound depends on the extent to which the electrostatic forces holding the ions of the compound together can be overcome. The solubility changes significantly with temperature; most metal compounds are more soluble as the temperature increases. Additionally, the solubility is affected by the other constituents present in a waste. As a general rule, nitrates, chlorides, and sulfates are more soluble than hydroxides, sulfides, carbonates, and phosphates.

An important concept related to treatment of the soluble metal compounds is pH. This term provides a measure of the extent to which a solution contains either an excess of hydrogen or hydroxide ions. The pH scale ranges from 0 to 14, with 0 being the most acidic, 14 representing the highest alkalinity or hydroxide ion (OH^-) content, and 7.0 being neutral.

When hydroxide is used, as is often the case, to precipitate the soluble metal compounds, the pH is frequently monitored to ensure that sufficient treatment chemicals are added. It is important to point out that pH is not a good measure of treatment chemical addition for compounds other than hydroxides; when sulfide is used, for example, facilities might use an oxidation-reduction potential (ORP) meter correlation to ensure that sufficient treatment chemical is used.

Following conversion of the relatively soluble metal compounds to metal precipitates, the effectiveness of chemical precipitation is a function of the physical removal, which usually relies on a settling process. A particle of a specific size, shape, and composition will settle at a specific velocity, as described by Stokes' Law. For a batch system, Stokes' law is a good predictor of settling time because the pertinent particle parameters remain essentially constant. Nevertheless, in practice, settling time for a batch system is normally determined by empirical testing. For a continuous system, the theory of settling is complicated by factors such as turbulence, short-circuiting, and velocity gradients, thereby increasing the importance of the empirical tests.

(3) Description of the chemical precipitation process. The equipment and instrumentation required for chemical precipitation vary depending on whether the system is batch or continuous. Both operations

are discussed below; a schematic of the continuous system is shown in Figure 3-5.

For a batch system, chemical precipitation requires only a feed system for the treatment chemicals and a second tank in which the waste can be treated and allowed to settle. When lime is used, it is usually added to the reaction tank in a slurry form. In a batch system, the supernate is usually analyzed before discharge, thus minimizing the need for instrumentation.

In a continuous system, additional tanks are necessary, as well as instrumentation to ensure that the system is operating properly. In this system, the first tank that the wastewater enters is referred to as an equalization tank. This is where the waste can be mixed to provide more uniformity, minimizing wide swings in the type and concentration of constituents being sent to the reaction tank. It is important to reduce the variability of the waste sent to the reaction tank because control systems inherently are limited with regard to the maximum fluctuations that can be managed.

Following equalization, the waste is pumped to a reaction tank where treatment chemicals are added; this is done automatically by using instrumentation that senses the pH of the system and then pneumatically adjusts the position of the treatment chemical feed valve so that the design pH value is achieved. Both the complexity and the effectiveness of the automatic control system will vary depending on the variation in the waste and the pH range that is needed to properly treat the waste.

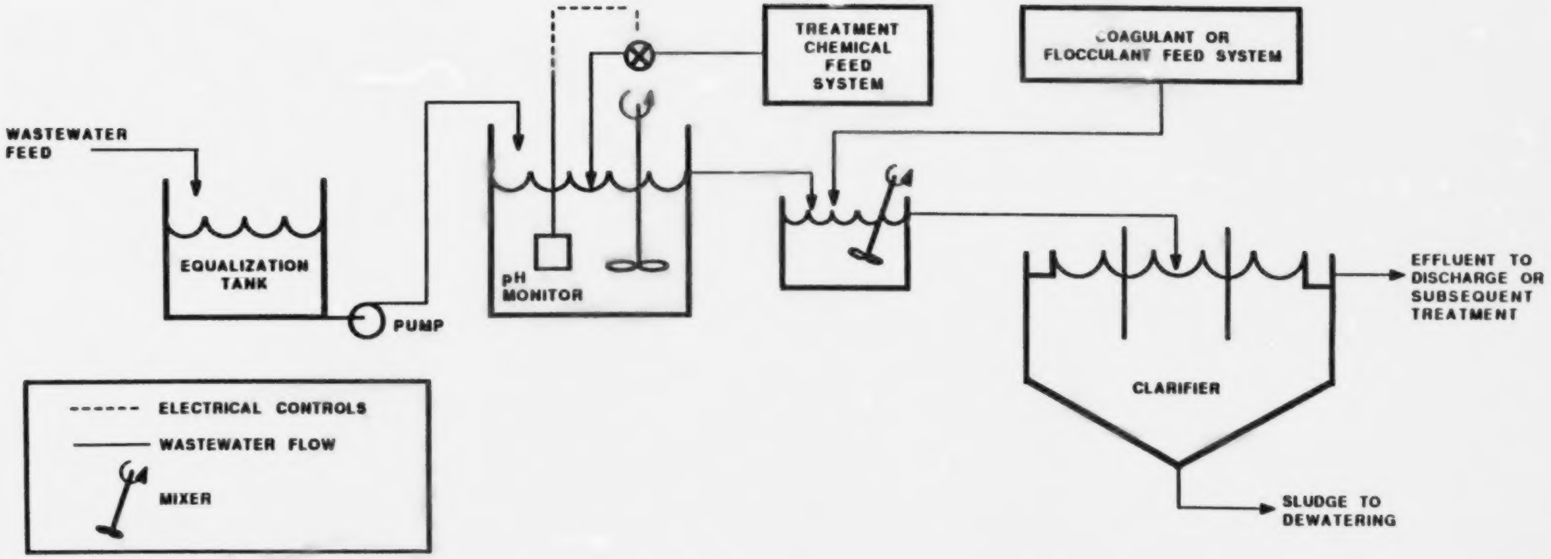

WASTEWATER FEED
EQUALIZATION TANK
PUMP
pH MONITOR
TREATMENT CHEMICAL FEED SYSTEM
COAGULANT OR FLOCCULANT FEED SYSTEM
CLARIFIER
EFFLUENT TO DISCHARGE OR SUBSEQUENT TREATMENT
SLUDGE TO DEWATERING
------ ELECTRICAL CONTROLS
WASTEWATER FLOW
MIXER

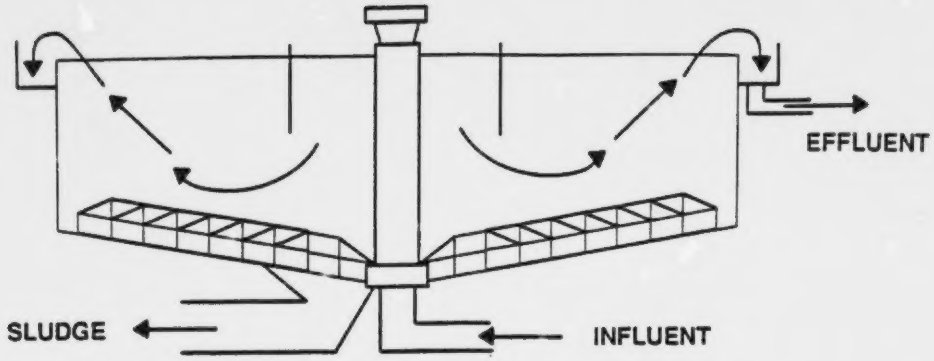
FIGURE 3-5 CONTINUOUS CHEMICAL PRECIPITATION

An important aspect of the reaction tank design is that the contents be well mixed so that the waste and the treatment chemicals are both dispersed throughout the tank to ensure comingling of the reactant and the treatment chemicals. In addition, effective dispersion of the treatment chemicals throughout the tank is necessary to properly monitor and thereby control the amount of treatment chemicals added.

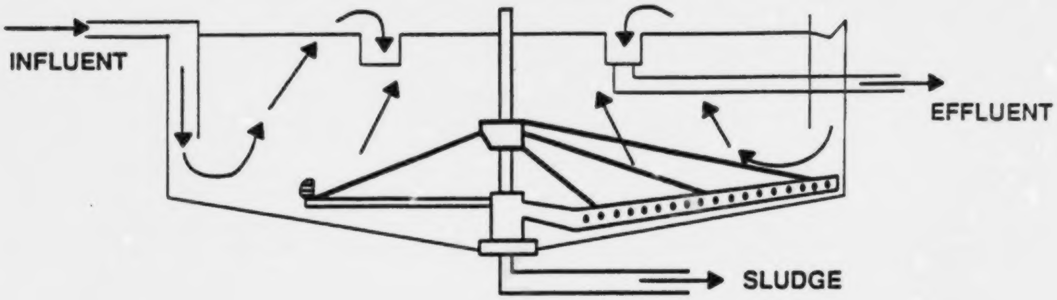
After the waste is reacted with the treatment chemical, it flows to a quiescent tank where the precipitate is allowed to settle and subsequently be removed. Settling can be chemically assisted through the use of flocculating compounds. Flocculants increase the particle size and density of the precipitated solids, both of which increase the rate of settling. The particular flocculating agent that will best improve settling characteristics will vary depending on the particular waste; selection of the flocculating agent is generally accomplished by performing laboratory bench tests. Settling can be conducted in a large tank by relying solely on gravity or can be mechanically assisted through the use of a circular clarifier or an inclinded separator. Schematics of the latter two separators are shown in Figures 3-6 and 3-7.

Filtration can be used for further removal of precipitated residuals both in cases where the settling system is underdesigned and in cases where the particles are difficult to settle. Polishing filtration is discussed in a separate technology section.

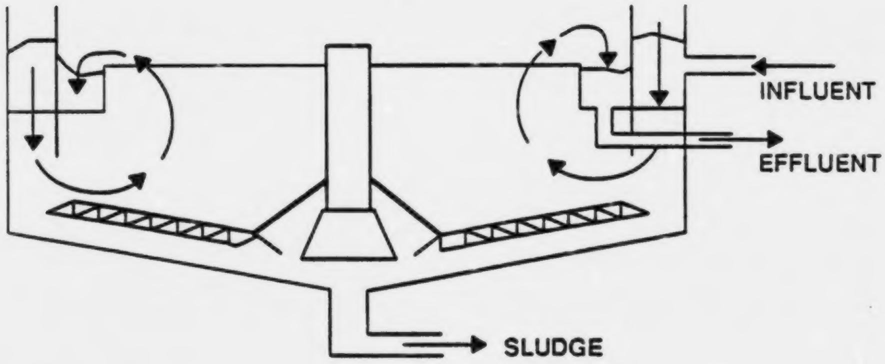
(4) Waste characteristics affecting performance. In determining whether chemical preciptation is likely to achieve the same level of performance on an untested waste as on a previously tested waste, we will


EFFLUENT
SLUDGE
INFLUENT

CENTER FEED CLARIFIER WITH SCRAPER SLUDGE REMOVAL SYSTEM


INFLUENT
EFFLUENT
SLUDGE

RIM FEED - CENTER TAKEOFF CLARIFIER WITH HYDRAULIC SUCTION SLUDGE REMOVAL SYSTEM


INFLUENT
EFFLUENT
SLUDGE

RIM FEED - RIM TAKEOFF CLARIFIER

FIGURE 3-6 CIRCULAR CLARIFIERS

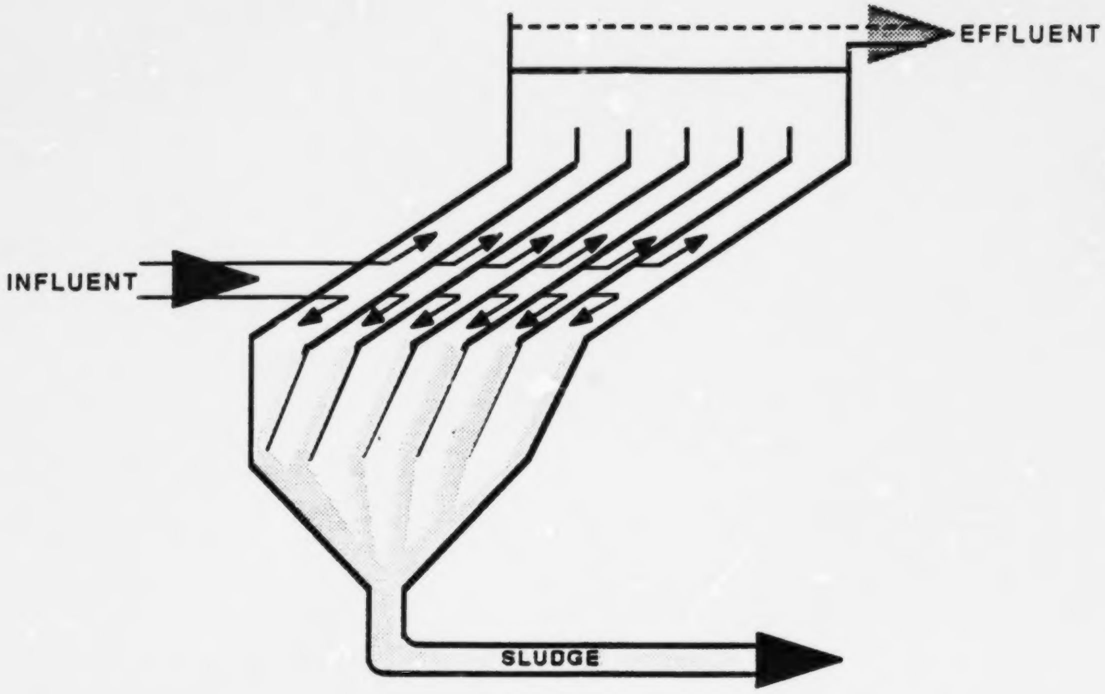

EFFLUENT
INFLUENT
SLUDGE

FIGURE 3-7
INCLINED PLATE SETTLER

examine the following waste characteristics: (1) the concentration and type of the metal(s) in the waste, (2) the concentration of suspended solids (TSS), (3) the concentration of dissolved solids (TDS), (4) whether the metal exists in the wastewater as a complex, and (5) the oil and grease content. These parameters affect the chemical reaction of the metal compound, the solubility of the metal precipitate, or the ability of the precipitated compound to settle.

(a) Concentration and type of metals. For most metals, there is a specific pH at which the metal hydroxide is least soluble. As a result, when a waste contains a mixture of many metals, it is not possible to operate a treatment system at a single pH that is optimal for the removal of all metals. The extent to which this affects treatment depends on the particular metals to be removed and their concentrations. One approach is to operate multiple precipitations, with intermediate settling, when the optimum pH occurs at markedly different levels for the metals present. The individual metals and their concentrations can be measured using EPA Method 6010.

(b) Concentration and type of total suspended solids (TSS). Certain suspended solid compounds are difficult to settle because of their particle size or shape. Accordingly, EPA will evaluate this characteristic in assessing the transfer of treatment performance. Total suspended solids can be measured by EPA Wastewater Test Method 160.2.

(c) Concentration of total dissolved solids (TDS). Available information shows that total dissolved solids can inhibit settling. The literature states that poor flocculation is a consequence of high TDS and shows that higher concentrations of total suspended solids are found in treated residuals. Poor flocculation can adversely affect the degree to which precipitated particles are removed. Total dissolved solids can be measured by EPA Wastewater Test Method 160.1.

(d) Complexed metals. Metal complexes consist of a metal ion surrounded by a group of other inorganic or organic ions or molecules (often called ligands). In the complexed form, the metals have a greater solubility and, therefore, may not be as effectively removed from solution by chemical precipitation. EPA does not have an analytical method to determine the amount of complexed metals in the waste. The Agency believes that the best measure of complexed metals is to analyze for some common complexing compounds (or complexing agents) generally found in wastewater for which analytical methods are available. These complexing agents include ammonia, cyanide, and EDTA. The analytical method for cyanide is EPA Method 9010, and the method for EDTA is ASTM Method D3113. Ammonia can be analyzed using EPA Wastewater Test Method 350.

(e) Oil and grease content. The oil and grease content of a particular waste directly inhibits the settling of the precipitate. Suspended oil droplets float in water and tend to suspend particles such as chemical precipitates that would otherwise settle out of the solution. Even with the use of coagulants or flocculants, the separation of the precipitate is less effective. Oil and grease content can be measured by EPA Method 9071.

(5) Design and operating parameters. The parameters that EPA will evaluate when determining whether a chemical precipitation system is well designed are: (1) design value for treated metal concentrations, as well as other characteristics of the waste used for design purposes (e.g., total suspended solids), (2) pH, (3) residence time, (4) choice of treatment chemical, (5) choice of coagulant/flocculant, and (6) mixing. The reasons for which EPA believes these parameters are important to a design analysis are cited below, along with an explanation of why other design criteria are not included in this analysis.

(a) Treated and untreated design concentrations. When determining whether to sample a particular facility, EPA pays close attention to the treated concentration that the system is designed to achieve. Since the system will seldom outperform its design, EPA must evaluate whether the design is consistent with best demonstrated practice.

The untreated concentrations that the system is designed to treat are important in evaluating any treatment system. Operation of a chemical precipitation treatment system with untreated waste concentrations in excess of design values can easily result in poor performance.

(b) pH. The pH is important, because it can indicate that sufficient treatment chemical (e.g., lime) has been added to convert the metal constituents in the untreated waste to forms that will precipitate. The pH also affects the solubility of metal hydroxides and sulfides and thus directly impacts the effectiveness of removal. In practice, the design pH is determined by empirical bench testing, often referred to as "jar" testing. The temperature at which the "jar" testing is conducted is important in that it also affects the solubility of the metal precipitates. Operation of a treatment system at temperatures above the design temperature can result in poor performance. In assessing the operation of a chemical precipitation system, EPA prefers to use continuous data on the pH and periodic temperature conditions throughout the treatment period.

(c) Residence time. The residence time is important because it impacts the completeness of the chemical reaction to form the metal precipitate and, to a greater extent, the amount of precipitate that settles out of solution. In practice, it is determined by "jar" testing. For continuous systems, EPA will monitor the feed rate to ensure that the system is operated at design conditions. For batch systems, EPA will want information on the design parameter used to determine sufficient settling time (e.g., total suspended solids).

(d) Choice of treatment chemical. A choice must be made as to what type of precipitating agent (i.e., treatment chemical) will be used. The factor that most affects this choice is the type of metal constituents to be treated. Other design parameters, such as pH, residence time, and choice of coagulant/flocculant agents, are based on the selection of the treatment chemical.

(e) Choice of coagulant/flocculant. This is important because these compounds improve the settling rate of the precipitated metals and allows for smaller systems (i.e., those with a lower retention time) to achieve the same degree of settling as much larger systems. In practice, the choice of the best agent and the required amount is determined by "jar" testing.

(f) Mixing. The degree of mixing is a complex assessment that includes, among other things, the energy supplied, the time the material is mixed, and the related turbulence effects of the specific size and shape of the tank. EPA will consider whether mixing is provided and whether the type of mixing device is one that could be expected to achieve uniform mixing. For example, EPA may not use data from a chemical precipitation treatment system in which an air hose was placed in a large tank to achieve mixing.

3.2.4 Sludge Filtration

(1) Applicability and use of sludge filtration. Sludge filtration, also known as sludge dewatering or cake-formation filtration, is a technology used on wastes that contain high concentrations of suspended solids, generally higher than 1 percent. The remainder of the waste is essentially water. Sludge filtration is applied to sludges, typically those that have settled to the bottom of clarifiers, for dewatering. After filtration, these sludges can be dewatered to 20 to 50 percent solids.

(2) Underlying principle of operation. The basic principle of filtration is the separation of particles from a mixture of fluids and particles by a medium that permits the flow of the fluid but retains the particles. As would be expected, larger particles are easier to separate

from the fluid than smaller particles. Extremely small particles, in the colloidal range, may not be filtered effectively and may appear in the treated waste. To mitigate this problem, the wastewater should be treated prior to filtration to modify the particle size distribution in favor of the larger particles, by the use of appropriate precipitants, coagulants, flocculants, and filter aids. The selection of the appropriate precipitant or coagulant is important because it affects the particles formed. For example, lime neutralization usually produces larger, less gelatinous particles than does caustic soda precipitation. For larger particles that become too small to filter effectively because of poor resistance to shearing, shear resistance can be improved by the use of coagulants and flocculants. Also, if pumps are used to feed the filter, shear can be minimized by designing for a lower pump speed or by using a low-shear type of pump.

(3) Description of the sludge filtration process. For sludge filtration, settled sludge is either pumped through a cloth-type filter medium (such as in a plate and frame filter that allows solid "cake" to build up on the medium) or the sludge is drawn by vacuum through the cloth medium (such as on a drum or vacuum filter, which also allows the solids to build). In both cases the solids themselves act as a filter for subsequent solids removal. For a plate and frame type filter, solids are removed by taking the unit off line, opening the filter, and scraping the solids off. For the vacuum type filter, the cake is removed continuously. For a specific sludge, the plate and frame type filter

will usually produce a drier cake than will a vacuum filter. Other types of sludge filters, such as belt filters, are also used for effective sludge dewatering.

(4) Waste characteristics affecting performance. The following characteristics of the waste will affect performance of a sludge filtration unit: (1) size of particles and (2) type of particles.

(a) Size of particles. The smaller the particle size, the more the particles tend to go through the filter media. This is especially true for a vacuum filter. For a pressure filter (like a plate and frame), smaller particles may require higher pressures for equivalent throughput, since the smaller pore spaces between particles create resistance to flow.

(b) Type of particles. Some solids formed during metal precipitation are gelatinous in nature and cannot be dewatered well by cake-formation filtration. In fact, for vacuum filtration a cake may not form at all. In most cases solids can be made less gelatinous by use of the appropriate coagulants and coagulant dosage prior to clarification, or after clarification but prior to filtration. In addition, the use of lime instead of caustic soda in metal precipitation will reduce the formation of gelatinous solids. The addition of filter aids, such as lime or diatomaceous earth, to a gelatinous sludge will help significantly. Finally, precoating the filter with diatomaceous earth prior to sludge filtration will assist in dewatering gelatinous sludges.

(5) Design and operating parameters. For sludge filtration, the following design and operating variables affect performance: (1) type of filter selected, (2) size of filter selected, (3) feed pressure, and (4) use of coagulants or filter aids.

(a) Type of filter. Typically, pressure type filters (such as a plate and frame) will yield a drier cake than a vacuum type filter and will also be more tolerant of variations in influent sludge characteristics. Pressure type filters, however, are batch operations; when cake is built up to the maximum depth physically possible (constrained by filter geometry), or to the maximum design pressure, the filter is turned off while the cake is removed. A vacuum filter is a continuous device (i.e., cake discharges continuously), but it will usually be much larger than a pressure filter with the same capacity. A hybrid device is a belt filter, which mechanically squeezes sludge between two continuous fabric belts.

(b) Size of filter. As with in-depth filters, the larger the filter, the greater its hydraulic capacity and the longer the filter runs between cake discharges.

(c) Feed pressure. This parameter impacts both the design pore size of the filter and the design flow rate. In treating waste, it is important that the design feed pressure not be exceeded; otherwise, particles may be forced through the filter medium, resulting in ineffective treatment.

(d) Use of coagulants. Coagulants and filter aids may be mixed with filter feed prior to filtration. Their effect is particularly significant for vacuum filtration since in this instance they may make the difference between no cake and a relatively dry cake. In a pressure filter, coagulants and filter aids will also significantly improve hydraulic capacity and cake dryness. Filter aids, such as diatomaceous earth, can be precoated on filters (vacuum or pressure) for sludges that are particularly difficult to filter. The precoat layer acts somewhat like an in-depth filter in that sludge solids are trapped in the precoat pore spaces. Use of precoats and most coagulants or filter aids significantly increases the amount of sludge solids to be disposed of. However, polyelectrolyte coagulant usage usually does not increase sludge volume significantly because the dosage is low.

3.2.5 Stabilization

Stabilization refers to a broad class of treatment processes that chemically reduce the mobility of hazardous constituents in a waste. Solidification and fixation are other terms that are sometimes used synonymously for stabilization or to describe specific variations within the broader class of stabilization. Related technologies are encapsulation and thermoplastic binding; however, EPA considers these technologies to be distinct from stabilization in that the operational principles are significantly different.

(1) Applicability and use of stabilization. Stabilization is used when a waste contains metals that will leach from the waste when it is contacted by water. In general, this technology is applicable to wastes

containing BDAT list metals and having a high filterable solids content, low TOC content, and low oil and grease content. This technology is commonly used to treat residuals generated from treatment of electroplating wastewaters. For some wastes, an alternative to stabilization is metal recovery.

(2) Underlying Principles of Operation. The basic principle underlying this technology is that stabilizing agents and other chemicals are added to a waste to minimize the amount of metal that leaches. The reduced leachability is accomplished by the formation of a lattice structure and/or chemical bonds that bind the metals to the solid matrix and thereby limit the amount of metal constituents that can be leached when water or a mild acid solution comes into contact with the waste material.

Two principal stabilization processes are used--cement-based and lime-based. A brief discussion of each is provided below. In both cement-based or lime/pozzolan-based techniques, the stabilizing process can be modified through the use of additives, such as silicates, that control curing rates or enhance the properties of the solid material.

(a) Portland cement-based process. Portland cement is a mixture of powdered oxides of calcium, silica, aluminum, and iron, produced by kiln burning of materials rich in calcium and silica at high temperatures (i.e., 1400 to 1500°C). When the anhydrous cement powder is mixed with water, hydration occurs and the cement begins to set. The chemistry involved is complex because many different reactions occur depending on the composition of the cement mixture.

As the cement begins to set, a colloidal gel of indefinite composition and structure is formed. Over a period of time, the gel swells and forms a matrix composed of interlacing, thin, densely packed silicate fibrils. Constituents present in the waste slurry (e.g., hydroxides and carbonates of various heavy metals, are incorporated into the interstices of the cement matrix. The high pH of the cement mixture tends to keep metals in the form of insoluble hydroxide and carbonate salts.) It has been hypothesized that metal ions may also be incorporated into the crystal structure of the cement matrix, but this hypothesis has not been verified.

(b) Lime/pozzolan-based process. Pozzolan, which contains finely divided, noncrystalline silica (e.g., fly ash or components of cement kiln dust), is a material that is not cementitious in itself but becomes so upon the addition of lime. Metals in the waste are converted to silicates or hydroxides, which inhibit leaching. Additives, again, can be used to reduce permeability and thereby further decrease leaching potential.

(3) Description of stabilization processes. In most stabilization processes, the waste, stabilizing agent, and other additives, if used, are mixed and then pumped to a curing vessel or area and allowed to cure. The actual operation (equipment requirements and process sequencing) will depend on several factors such as the nature of the waste, the amount of waste, the location of the waste in relation to the

disposal site, the particular stabilization formulation to be used, and the curing rate. After curing, the solid formed is recovered from the processing equipment and shipped for final disposal.

In instances where waste contained in a lagoon is to be treated, the material should first be transferred to mixing vessels where stabilizing agents are added. The mixed material is then fed to a curing pad or vessel. After curing, the solid formed is removed for disposal. Equipment commonly used also includes facilities to store waste and chemical additives. Pumps can be used to transfer liquid or light sludge wastes to the mixing pits and pumpable uncured wastes to the curing site. Stabilized wastes are then removed to a final disposal site.

Commercial concrete mixing and handling equipment generally can be used with wastes. Weighing conveyors, metering cement hoppers, and mixers similar to concrete batching plants have been adapted in some operations. Where extremely dangerous materials are being treated, remote-control and in-drum mixing equipment, such as that used with nuclear waste, can be employed.

(4) Waste characteristics affecting performance. In determining whether stabilization is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will focus on the characteristics that inhibit the formation of either the chemical bonds or the lattice structure. The four characteristics EPA has identified as affecting treatment performance are the presence of (1) fine particulates, (2) oil and grease, (3) organic compounds, and (4) certain inorganic compounds.

(a) Fine particulates. For both cement-based and lime/pozzolan-based processes, the literature states that very fine solid materials (i.e., those that pass through a No. 200 mesh sieve, 74 um particle size) can weaken the bonding between waste particles and cement by coating the particles. This coating can inhibit chemical bond formation and thereby decrease the resistance of the material to leaching.

(b) Oil and grease. The presence of oil and grease in both cement-based and lime/pozzolan-based systems results in the coating of waste particles and the weakening of the bonding between the particle and the stabilizing agent. This coating can inhibit chemical bond formation and thereby decrease the resistance of the material to leaching.

(c) Organic compounds. The presence of organic compounds in the waste interferes with the chemical reactions and bond formation, which inhibits curing of the stabilized material. This results in a stabilized waste that has decreased resistance to leaching.

(d) Sulfate and chlorides. The presence of certain inorganic compounds will interfere with the chemical reactions, weakening bond strength and prolonging setting and curing time. Sulfate and chloride compounds may reduce the dimensional stability of the cured matrix, thereby increasing leachability potential.

Accordingly, EPA will examine these constituents when making decisions regarding transfer of treatment standards based on stabilization.

(5) Design and operating parameters. In designing a stabilization system, the principal parameters that are important to optimize so that the amount of leachable metal constituents is minimized are (1) selection of stabilizing agents and other additives, (2) ratio of waste to stabilizing agents and other additives, (3) degree of mixing, and (4) curing conditions.

(a) Selection of stabilizing agents and other additives. The stabilizing agent and additives used will determine the chemistry and structure of the stabilized material and, therefore, will affect the leachability of the solid material. Stabilizing agents and additives must be carefully selected based n the chemical and physical characteristics of the waste to be stabilized. For example, the amount of sulfates in a waste must be considered when a choice is being made between a lime/pozzolan-based and a Portland cement-based system.

To select the type of stabilizing agents and additives, the waste should be tested in the laboratory with a variety of materials to determine the best combination.

(b) Amount of stabilizing agents and additives. The amount of stabilizing agents and additives is a critical parameter in that sufficient stabilizing materials are necessary in the mixture to bind the waste constituents of concern properly, thereby making them less susceptible to leaching. The appropriate weight ratios of waste to stabilizing agent and other additives are established empirically by setting up a series of laboratory tests that allow separate leachate testing of different mix ratios. The ratio of water to stabilizing agent (including water in waste) will also impact the strength and leaching characteristics of the stabilized material. Too much water will cause low strength; too little will make mixing difficult and, more importantly, may not allow the chemical reactions that bind the hazardous constituents to be fully completed.

(c) Mixing. This parameter includes both the type and duration of mixing. Mixing is necessary to ensure homogeneous distribution of the waste and the stabilizing agents. Both undermixing and overmixing are undesirable. The first condition results in a nonhomogeneous mixture; therefore, areas will exist within the waste where waste particles are neither chemically bonded to the stabilizing agent nor physically held within the lattice structure. Overmixing, on the other hand, may inhibit gel formation and ion adsorption in some stabilization systems. As with the relative amounts of waste, stabilizing agent, and additives within the system, optimal mixing conditions generally are determined through laboratory tests. During treatment it is important to monitor the degree (i.e., type and duration) of mixing to ensure that it reflects design conditions.

(d) Curing conditions. Curing conditions include the duration of curing and the ambient curing conditions (temperature and humidity). The duration of curing is a critical parameter to ensure that the waste particles have had sufficient time in which to form stable chemical bonds and/or lattice structures. The time necessary for complete stabilization depends upon the waste type and the stabilization used. The performance of the stabilized waste (i.e., the levels of constituents in the leachate) will be highly dependent upon whether complete stabilization has occurred. Higher temperatures and lower humidity increase the rate of curing by increasing the rate of evaporation of water from the solidification mixtures. If temperatures are too high, however, the evaporation rate can be excessive, resulting in too little water being available for completion of the stabilization reaction. The duration of the curing process, which should also be determined during the design stage, typically will range between 7 and 28 days.

4. PERFORMANCE DATA BASE

This section presents performance data associated with the demonstrated technologies for K001 waste. Performance data include the BDAT list constituent concentrations in untreated and treated waste samples, the operating data collected during treatment of the waste samples, design values for the treatment technologies, and data on waste characteristics that affect treatment performance. EPA has presented all such data to the extent that they are available.

EPA's use of these data in determining the technologies that represent BDAT, and for developing treatment standards, is described in Sections 5 and 7, respectively.

4.1 BDAT List Organics

EPA tested rotary kiln incineration to demonstrate the actual performance achievable by this technology for treatment of K001. Since EPA is not aware of any generator or TSD facilities currently using incineration for treatment of wastes containing high percentages of K001, the K001 wastes were collected from a generator and incinerated at EPA's test facility, as well as at another test facility. The rationale for selecting the generator chosen for waste collection is presented in the Administrative Record for K001.

The Agency has nine data sets (matched pairs of untreated and treated data points) for K001 wastes using rotary kiln incineration. Specifically, six of the data sets are from the testing of a K001 waste from the use of creosote-based wood preservatives (K001 - Creosote) and three data sets represent a pentachlorophenol K001 waste (K001 - PCP). These data, presented in Tables 4-1 through 4-9, show total waste concentrations for all BDAT list constituents detected in the untreated wastes, the residual ash, and the scrubber water. The design and operating data collected during the incineration of K001 wastes are presented in Tables 4-10 through 4-13. Each of the nine data sets provides performance for the BDAT list organics detected in the untreated K001 wastes. In general, the number of BDAT list organic constituents detected in the untreated waste varies for each of the nine sample sets. The treated data represent total waste concentrations found in the scrubber water and the ash from rotary kiln incineration. All of these BDAT list organic constituents detected in the untreated waste were not detected in either the scrubber water or the ash from rotary kiln incineration.

The Agency does not have performance data for treatment of the BDAT list organics present in K001 using fuel substitution.

4.2 BDAT List Metals Treatment Data

4.2.1 Wastewater

The Agency does not have performance data on treatment of the BDAT metals in the scrubber water generated specifically from the incineration of K001. However, EPA does have data from the Agency's testing of a metal-bearing wastewater at Envirite Corporation. The Agency believes these data represent a level of treatment performance that can be achieved for the K001 scrubber water by using chemical precipitation, primarily using lime as the treatment chemical, and sludge filtration.

The data collected for the Envirite treatment system consist of 11 untreated and treated sample sets. The untreated waste was a metal-containing wastewater that was a mixture of F006, D002, D003, and K062 wastewaters. The performance data for the Envirite wastewater treatment system are shown in Table 4-14. These data reflect total concentrations for BDAT list metals in the untreated and treated wastewaters.

EPA reviewed the characterization data for the K001 scrubber water, as well as data on parameters that would affect the performance of the Envirite treatment system. The concentrations of untreated metals in the Envirite wastewater are greater than the metal concentrations in the K001 scrubber water. Specifically, the principal metals in the K001 scrubber water are present at concentrations of less than 11 mg/l for zinc and 5.4 mg/l for lead. In the Envirite metal-containing wastewater, the concentrations for zinc range from 3.9 to 171 mg/l and the concentrations for lead range from 10 to 212 mg/l. Both the Envirite wastewater and the K001 scrubber water have low oil and grease contents. In conclusion, these data show that the K001 scrubber water could be treated to the same levels as the Envirite metal-containing wastewaters.

4.2.2 Nonwastewater

EPA does not have performance data on treatment of BDAT list metals in either the ash generated by rotary kiln incineration of K001 waste or the filter cake generated by treatment of the K001 scrubber water. Industry, however, submitted performance data showing treatment of F006 waste (an electroplating sludge) by stabilization, the demonstrated technology for these K001 nonwastewaters. These F006 data, presented in Table 4-15, reflect total waste and TCLP leachate concentrations for BDAT list metals in the untreated waste and TCLP leachate concentrations for metals in the treated waste. The 209 treated data points represent F006 wastes from various electroplating industries, including auto part manufacturing, aircraft overhauling, zinc plating, small engine manufacturing, and circuit board manufacturing.

The Agency believes that these F006 data can be used to represent the performance of stabilization on the treatment sludge that would be generated from treatment of K001 scrubber water by chemical precipitation followed by sludge filtration. An analysis of the waste characteristics that affect stabilization performance indicates that the K001 ash and filter cake would be less difficult to treat than the F006 waste. The K001 scrubber water data show that this residual contains metals at concentrations ranging from less than 0.001 mg/l to 11 mg/l, with the highest concentration for lead being 5.4 mg/l. Precipitation of this waste would yield a precipitated residue with an estimated concentration of up to 110 mg/kg for lead, with a water content and a filterable solids concentration similar to those of the F006 wastes. A review of the F006 wastes shows that they contain BDAT list metals at concentrations ranging up to 42,900 ppm.

The Agency believes that the F006 data can also be used to represent the performance of stabilization on the K001 ash. Concentrations of BDAT list metals in the untreated K001 waste range up to 190 ppm for lead and

200 ppm for zinc, while their maximum concentrations in the ash are 5.2 and 3.2 ppm, respectively. Concentrations for these BDAT list metals in the untreated F006 data were as high as 24,500 ppm for lead and 90,200 ppm for zinc. Therefore, the K001 nonwastewater residuals would be easier to treat than the F006 waste. EPA expects that the K001 ash is also easier to stabilize because such ash residuals contain metals in the form of oxides, which have been shown to leach at lower concentrations than the typical F006 hydroxides.

Other stabilization data were available to EPA and can be found in the Administrative Record. They were eliminated from further consideration as sources for transferring data to develop treatment standards because of one or a combination of the reasons provided below:

1. The waste treated was less similar to the K001 ash or expected precipitated residuals than the waste for which performance data are presented;
2. The performance data do not show substantial treatment for the constituents to be regulated (selected in Section 6);
3. Design and operating data, or lack of such data, do not enable the Agency to ascertain whether the treatment system was well designed and well operated; or
4. The measure of performance is not consistent with EPA's approach in evaluating treatment of metals by stabilization; e.g., EP levels are given rather than TCLP leachate levels.

Table 4-1 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 1

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	56	<0.050	<0.050
Toluene	110	<0.050	<0.050
Ethyl benzene	57	<0.050	<0.050
Xylenes	120	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	21,000	<0.65	<0.010
Anthracene	15,000	<0.65	<0.010
Chrysene	4800	<0.85	<0.015
Fluorene	18,000	<0.65	<0.010
Naphthalene	42,000	<0.55	<0.010
Phenanthrene	41,000	<1.80	<0.030
Phenol	2400	<0.50	<0.010
Pyrene	17,000	<0.65	<0.010

Table 4-1 (continued)

Sample Set No. 1

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	0.035	<0.170
Arsenic	2.6	5.3	<0.020	0.041
Barium	63	81	0.38	0.76
Beryllium	<0.5	<0.5	<0.005	0.002
Cadmium	3.4	<2.0	0.020	0.87
Chromium	5.0	6.1	<0.035	0.35
Copper	35	86	0.020	0.42
Mercury	0.35	<1.25	<0.0025	0.016
Nickel	2.1	3.6	<0.075	0.48
Lead	170	<21	<0.21	2.5
Selenium	1.5	2.3	<0.020	0.057
Silver	<3.5	<3.5	<0.035	<0.035
Thallium	7.7	<2.5	<0.025	<0.028
Vanadium	<4.0	4.4	<0.040	0.040
Zinc	170	1.9	0.020	5.0

Reference: USEPA 1987a.

Table 4-2 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 2

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	60	<0.050	<0.050
Toluene	120	<0.050	<0.050
Ethyl benzene	56	<0.050	<0.050
Xylenes	130	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthalene	1000	<1.15	<0.020
Acenaphthene	15,000	<0.65	<0.010
Anthracene	7300	<0.65	<0.010
Chrysene	4200	<0.85	<0.015
Fluorene	12,000	<0.65	<0.010
Naphthalene	40,000	<0.55	<0.010
Phenanthrene	32,000	<1.80	<0.030
Phenol	3700	<0.50	<0.010
Pyrene	13,000	<0.65	<0.010

Table 4-2 (continued)

Sample Set No. 2

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	<0.17	<0.170
Arsenic	<2.0	5.3	<0.02	0.15
Barium	58	74	0.57	0.80
Beryllium	<0.5	<0.5	<0.005	<0.005
Cadmium	3.4	<2.0	<0.02	<0.99
Chromium	4.8	5.3	<0.035	0.74
Copper	32	100	0.030	0.50
Mercury	0.35	<1.25	<0.0025	0.060
Nickel	<7.5	4.6	<0.075	0.51
Lead	160	<21	<0.21	4.5
Selenium	1.4	1.9	<0.02	0.11
Silver	<3.5	<3.5	<0.035	0.010
Thallium	8.0	<2.5	<0.025	2.4
Vanadium	<4.0	4.1	<0.04	0.060
Zinc	170	1.8	0.050	7.1

Reference: USEPA 1987a.

Table 4-3 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 3

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	61	<0.050	<0.050
Toluene	100	<0.050	<0.050
Ethyl benzene	55	<0.050	<0.050
Xylenes	120	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	19,000	<0.65	<0.010
Anthracene	12,000	<0.65	<0.010
Chrysene	4800	<0.85	<0.015
Fluorene	16,000	<0.65	<0.010
Naphthalene	40,000	<0.55	<0.010
Phenanthrene	37,000	<1.80	<0.030
Phenol	3600	<0.50	<0.010
Pyrene	16,000	<0.65	<0.010

Table 4-3 (continued)

Sample Set No. 3

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	0.040	<0.17
Arsenic	2.1	9.0	<0.02	0.16
Barium	70	61	0.53	0.56
Beryllium	<0.5	<0.5	<0.005	0.001
Cadmium	3.1	<2.0	<0.02	0.95
Chromium	6.4	5.8	<0.035	0.60
Copper	39	98	0.030	0.43
Mercury	<1.25	<1.25	<0.0025	0.008
Nickel	2.1	5.0	0.020	0.56
Lead	150	<21	<0.21	3.5
Selenium	1.2	1.8	<0.020	0.090
Silver	<3.5	<3.5	<0.035	0.010
Thallium	6.8	<2.5	<0.025	2.8
Vanadium	<4.0	4.1	<0.040	0.040
Zinc	160	3.2	0.080	9.1

Reference: USEPA 1987a.

Table 4-4 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 4

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	51	<0.050	<0.050
Toluene	110	<0.050	<0.050
Ethyl benzene	72	<0.050	<0.050
Xylenes	130	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	16,000	<0.65	<0.010
Anthracene	8500	<0.65	<0.010
Chrysene	4100	<0.85	<0.015
Fluorene	14,000	<0.65	<0.010
Naphthalene	32,000	<0.55	<0.010
Phenanthrene	29,000	<1.80	<0.030
Phenol	3900	<0.50	<0.010
Pyrene	12,000	<0.65	<0.010

Table 4-4 (continued)

Sample Set No. 4

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	0.040	0.040
Arsenic	2.5	10	<0.020	0.28
Barium	59	48	0.31	1.0
Beryllium	<0.5	<0.5	<0.005	0.001
Cadmium	2.4	<2.0	<0.020	1.2
Chromium	7.0	8.7	<0.035	1.0
Copper	39	110	<0.030	0.51
Mercury	0.40	<1.25	<0.0025	0.29
Nickel	2.8	5.2	<0.075	0.60
Lead	110	<21	<0.210	5.4
Selenium	1.1	2.5	<0.020	0.12
Silver	<3.5	<3.5	<0.035	0.020
Thallium	5.3	<2.5	<0.025	3.4
Vanadium	0.82	4.2	<0.040	0.080
Zinc	120	2.8	0.010	11

Reference: USEPA 1987a.

Table 4-5 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 5

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	58	<0.050	<0.050
Toluene	110	<0.050	<0.050
Ethyl benzene	71	<0.050	<0.050
Xylenes	130	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	19,000	<0.65	<0.010
Anthracene	7400	<0.65	<0.010
Chrysene	4200	<0.85	<0.015
Fluorene	16,000	<0.65	<0.010
Naphthalene	29,000	<0.55	<0.010
Phenanthrene	32,000	<1.80	<0.030
Phenol	2400	<0.50	<0.010
Pyrene	15,000	<0.65	<0.010

Table 4-5 (continued)

Sample Set No. 5

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	0.040	<0.170
Arsenic	0.7	13	0.025	0.25
Barium	12	56	0.22	0.90
Beryllium	<0.5	<0.5	<0.005	0.002
Cadmium	0.79	<2.0	<0.020	0.45
Chromium	1.6	10	<0.035	0.65
Copper	12	130	0.008	0.45
Mercury	0.79	<1.25	<0.0025	0.19
Nickel	1.8	6.8	<0.075	0.70
Lead	37	<21	<0.210	3.3
Selenium	0.3	2.6	0.004	0.038
Silver	<3.5	<3.5	<0.035	0.010
Thallium	2.2	<2.5	<0.025	3.8
Vanadium	<4.0	5.2	0.020	0.050
Zinc	40	3.0	0.030	8.2

Reference: USEPA 1987a.

Table 4-6 Rotary Kiln Incineration of K001 - Creosote

Sample Set No. 6

BOAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Benzene	83	<0.050	<0.050
Toluene	170	<0.050	<0.050
Ethyl benzene	87	<0.050	<0.050
Xylenes	170	<0.050	<0.050

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	17,000	<0.65	<0.010
Anthracene	9100	<0.65	<0.010
Chrysene	4300	<0.85	<0.015
Fluorene	14,000	<0.65	<0.010
Naphthalene	43,000	<0.55	<0.010
Phenanthrene	36,000	<1.80	<0.030
Phenol	3300	<0.50	<0.010
Pyrene	13,000	<0.65	<0.010

Table 4-6 (continued)

Sample Set No. 6

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) Total (mg/kg)	Treated nonwastewater (ash) TCLP (mg/l)	Treated wastewater (scrubber water) (mg/l)
Metals				
Antimony	<17	<17	0.040	0.040
Arsenic	2.6	11	<0.020	1.6
Barium	150	72	0.41	1.1
Beryllium	<0.5	<0.5	<0.005	0.001
Cadmium	3.5	<2.0	<0.020	0.46
Chromium	8.6	7.7	<0.035	0.89
Copper	38	86	0.070	0.35
Mercury	0.64	<1.25	<0.0025	0.54
Nickel	4.5	3.9	0.020	0.54
Lead	190	<21	<0.21	3.9
Selenium	1.1	2.8	<0.020	0.021
Silver	<3.5	<3.5	<0.035	0.0202
Thallium	3.3	<2.5	<0.025	4.0
Vanadium	1.9	4.8	<0.040	0.060
Zinc	200	2.5	0.002	8.2

Reference: USEPA 1987a.

Table 4-7 Rotary Kiln Incineration of K001 - PCP

Sample Set No. 7

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg) ✓	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Toluene	16	<0.010	<0.010

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenaphthene	13,000	<2.5	<0.050
Anthracene	9,300	<2.5	<0.050
Benzo(b &/or k) fluoroanthrene	940	<2.5	<0.050
Fluoranthrene	13,000	<2.5	<0.050
Fluorene	8,200	<2.5	<0.050
Naphthalene	26,000	<2.5	<0.050
Pentachlorophenol	970	<12.5	<0.250
Phenanthrene	28,000	<2.5	<0.050
Pyrene	9,200	<2.5	<0.050

Table 4-7 (continued)

Sample Set No. 7

BDAT List Constituent	Untreated waste (mg/kg)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated wastewater (mg/l)
Metals				
Antimony	<30	<30	<0.3	<0.3
Arsenic	2.9	0.8	<0.015	<0.01
Barium	30	74	0.32	0.12
Beryllium	<0.5	<0.5	<0.005	<0.005
Cadmium	0.5	<1.5	<0.015	<0.015
Chromium	1.5	8.2	<0.045	<0.045
Copper	6.7	6.8	<0.05	0.15
Lead	7.8	5.2	0.021	0.021
Mercury	0.11	<0.001	<0.001	<0.001
Nickel	<10	<10	<0.1	<0.1
Selenium	<2.5	<2.5	<0.025	<0.025
Silver	<4.5	<4.5	<0.045	<0.045
Thallium	<1.5	<1.5	<0.05	<0.015
Vanadium	<10	<10	<0.1	<0.1
Zinc	64	11	<0.03	1.1

Reference: USEPA 1987b.

Table 4-8 Rotary Kiln Incineration of K001 - PCP

Sample Set No. 8

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Toluene	10	<0.010	<0.010

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenapthene	18,000	<2.5	<0.050
Anthracene	13,000	<2.5	<0.050
Benz(a)anthracene	3,400	<2.5	<0.010
Benzo(a)pyrene	940	<2.5	<0.050
Benzo(b &/or k) fluroanthrene	2,300	<2.5	<0.050
Chrysene	3,600	<2.5	<0.050
Fluoranthrene	21,000	<2.5	<0.050
Fluorene	12,000	<2.5	<0.050
Naphthalene	43,000	<2.5	<0.050
Pentachlorophenol	3,000	<12.5	<0.250
Phenanthrene	42,000	<2.5	<0.050
Pyrene	15,000	<2.5	<0.050

Table 4-8 (continued)

Sample Set No. 8

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated wastewater (mg/l)
Metals				
Antimony	<30	<30	<0.3	<0.3
Arsenic	2.3	0.6	<0.015	0.12
Barium	19	21	0.19	0.24
Beryllium	<0.5	<0.5	<0.005	<0.005
Cadmium	0.6	<1.5	<0.015	<0.015
Chromium	2.7	1.1	<0.045	<0.045
Copper	11	3.0	<0.05	0.09
Lead	11	1.2	<0.01	0.18
Mercury	0.16	<0.001	<0.001	<0.001
Nickel	<10	<10	<0.1	<0.1
Selenium	<2.5	<2.5	<0.025	<0.025
Silver	<4.5	<4.5	<0.045	<0.045
Thallium	<1.5	<1.5	<0.05	<0.015
Vanadium	<10	<10	<0.1	<0.1
Zinc	58	2.1	<0.03	0.61

Reference: USEPA 1987b.

Table 4-9 Rotary Kiln Incineration of K001 - PCP

Sample Set No. 9

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Volatile Organics			
Toluene	39	<0.050	<0.010

	Untreated waste (mg/kg)	Treated nonwastewater (ash) (mg/kg)	Treated wastewater (scrubber water) (mg/l)
Semivolatile Organics			
Acenapthene	14,000	<2.5	<0.050
Anthracene	8,500	<2.5	<0.050
Benz(a)anthracene	2,500	<2.5	<0.010
Benzo(a)pyrene	620	<2.5	<0.050
Benzo(b &/or k) fluroanthrene	1,600	<2.5	<0.050
Fluoranthrene	15,000	<2.5	<0.050
Fluorene	9,000	<2.5	<0.050
Naphthalene	37,000	<2.5	<0.050
Pentachlorophenol	920	<12.5	<0.250
Phenanthrene	32,000	<2.5	<0.050
Pyrene	11,000	<2.5	<0.050

Table 4-9 (continued)

Sample Set No. 9

BDAT list constituent	Untreated waste (mg/kg)	Treated nonwastewater Total (mg/kg)	Treated nonwastewater TCLP (mg/l)	Treated wastewater (mg/l)
Metals				
Antimony	<30	<30	<0.3	<0.3
Arsenic	1.1	0.4	<0.015	0.11
Barium	17	21	0.25	0.39
Beryllium	<0.5	<0.5	<0.005	<0.005
Cadmium	0.4	<1.5	<0.015	<0.015
Chromium	2.1	1.2	<0.045	0.045
Copper	10	2	<0.05	0.07
Lead	6.3	0.96	<0.01	0.20
Mercury	0.064	<0.001	<0.001	0.003
Nickel	<10	<10	<0.1	<0.1
Selenium	<2.5	<2.5	<0.025	<0.025
Silver	<4.5	<4.5	<0.045	<0.045
Thallium	<1.5	<1.5	<0.05	<0.015
Vanadium	<10	<10	<0.1	<0.1
Zinc	30	2.1	<0.03	0.88

Raference: USEPA 1987b.

Table 4-10 Incinerator Operating Data for K001 - Creosote Sample Sets Numbers 1 and 2

Parameter	Sample collected	K001-creosote feed rate (lb/h)	Temperature (°F)		Kiln rotation speed (rpm)	Stack gas concentrations		
			Kiln	Afterburner		O_2 (%)	CO (ppm)	CO_2 (%)
10/5/87								
Kiln shakedown (before K001-C feed)	Scrubber pretest water	0	1720-1917	1984-2019	0.25			
10/6/87								
Start feed 11:03		180			0.25			
Begin test 12:10	Feed[a]	180	1694-1873	1932-2016	0.25	4-9	12-27	8-12
12:30		180	1771-1886	2008-2031	0.25	4-12	22-32	3-11
13:00		180	1828-1863	2014-2031	0.25	4-20	18-33	5-12
13:30		180	1835-1874	2014-2035	0.25	5-8	30-34	1-11
13:40	Ash Recycle[b]	180	1835-1838	2030-2033	0.25	6-8	32-34	9-10
14:00	Feed[a]	180	1790-1860	1996-2033	0.25	5-9	32-37	8-11
14:30		180	1800-1913	1996-2034	0.25	5-8	32-37	9-11
15:00		180	1838-1906	2019-2035	0.25	6-8	34-37	8-11
15:25	Ash Recycle[b]	180	1795-1838	2006-2019	0.25	7-9	30-37	8-10

[a] The feed samples were collected while the fiber packs were being packed. Six drums were used for the 2 days of testing. K001-C waste from two drums was incinerated for each sample set.

[b] The scrubber recycle tank was not blown down during the test series. Makeup water was added to replace water loss through the exhaust system. No chemicals were added to the scrubber water system. The recycle water samples were taken from the scrubber recirculation line.

Reference: USEPA 1987a.

Table 4-11 Incinerator Operating Data for K001 - Creosote Sample Sets Numbers 3 and 4

Parameter	Sample collected	K001-creosote feed rate (lb/h)	Temperature, (°F)		Kiln rotation speed (rpm)	Stack gas concentrations		
			Kiln	Afterburner		O_2 (%)	CO (ppm)	CO_2 (%)
10/6/87								
Continued feed								
17:10	Feed[a]	180			0.25			
17:30		180	1775-1840	1985-2002	0.25	6-10	39-42	8-10
18:00		180	1827-1875	2002-2026	0.25	6-9	31-42	8-11
18:30		180	1827-1875	2007-2026	0.25	6-9	39-41	8-10
18:40	Ash Recycle[b]	180	1822-1871	1993-2009	0.25	7-9	39-41	8-9
19:00	Feed[a]	180	1819-1826	1993-1997	0.25	7-9	37-41	8-10
19:30		180	1825-1878	1997-2008	0.25	7-9	31-42	8-11
20:00	Recycle[b]	180	1859-2028	1995-2093	0.25	4-9	39-720	8-13
20:15	Ash	180	1824-1859	1986-1995	0.25	7-10	35-38	8-10

---

[a] The feed samples were collected while the fiber packs were being packed. Six drums were used for the 2 days of testing. K001-C waste from two drums was incinerated for each sample set.

[b] The scrubber recycle tank was not blown down during the test series. Makeup water was added to replace water loss through the exhaust system. No chemicals were added to the scrubber water system. The recycle water samples were taken from the scrubber recirculation line.

Reference: USEPA 1987a.

Table 4-12 Incinerator Operating Data for K001 - Creosote Sample Sets Numbers 5 and 6

Parameter	Sample collected	K001-creosote feed rate (lb/h)	Temperature, (°F)		Kiln rotation speed, rpm	Stack gas concentrations		
			Kiln	Afterburner		O_2 (%)	CO (ppm)	CO_2 (%)
10/7/87								
Start feed 11:00		180			0.25			
Begin test 11:30	Feed[a]	180	1806-1841	2012-2020	0.25	4-8	15-18	9-12
12:00		180	1823-1912	2017-2039	0.25	2-9	15-30	9-13
12:30	Ash	180	1830-1886	2019-2025	0.25	4-8	17-24	9-11
	Recycle[b]							
13:00	Feed[a]	180	1845-1910	2011-2025	0.25	5-9	19-25	9-10
13:30		180	1829-1845	1999-2011	0.25	6-9	18-22	9-10
14:00		180	1827-1838	1997-2009	0.25	7-9	18-22	9-10
14:30		180	1827-1857	1999-2022	0.25	7-9	15-23	9-10
14:45	Ash	180	1844-1899	2022-2034	0.25	5-8	22-25	9-10
	Recycle[b]							
15:00		180	1896-1900	2026-2033	0.25	5-9	22-25	9-11

[a] The feed samples were collected while the fiber packs were being packed. Six drums were used for the 2 days of testing. K001-C waste from two drums was incinerated for each sample set.

[b] The scrubber recycle tank was not blown down during the test series. Makeup water was added to replace water loss through the exhaust system. No chemicals were added to the scrubber water system. The recycle water samples were taken from the scrubber recirculation line.

Reference: USEPA 1987a.

Table 4-13 Incinerator Operating Data for K001-PCP
Sample Sets Numbers 7 through 9

Parameter	Sample collected	Temperature (°F)		Kiln rotation speed (rpm)	Stack gas concentrations		
		Kiln	Afterburner		O2 (%)	CO (ppm)	CO_2 (%)
6/26/87							
Start feed (86 lb/h)	Feed[a]						
drum #1 15:30	Makeup water						
15:45							
16:00		1650-1682	1840-1869	0.2	5-9	<1	4->10
16:15		1720-1803	1823-1866	0.2	5-8	<1	7->10
16:30		1767-1826	1869-1875	0.2	5-9	<1	6->10
16:45		1777-1820	1872-1879	0.2	6-8	<1	8-10
17:00		1801-1873	1876-1895	0.2	5-8	<1	9->10
17:15		1813-1899	1889-1903	0.2	4-9	<1	8->10
17:30		1793-1936	1890-1914	0.2	4-9	<1	8->10
17:45		1861-1914	1885-1912	0.2	6-8	<1	9->10
18:00		1823-1914	1868-1888	0.2	5-16	<1	9->10
18:15		1782-1892	1859-1871	0.2	4-16	<1	9->10
18:30[b]		1877	1839	0.2	3-8	<1	8->10
18:45[b]		1924	1846	0.2	3-8	<1	8->10
19:00[b]		1970	1857	0.2	3-9	<1	8->10
19:15[b]	Blowdown ash[c]	2046	2033	0.2	3-10	<1	8->10

[a] The feed samples were collected while the fiber packs were being packed.

[b] Only one temperature value was available during this time period.

[c] The ash samples were collected from the ash bin after the ash cooled.

Reference: USEPA 1987b.

Table 4-14 Performance Data for Chemical Precipitation and Filtration on Mixed Waste Sampled by EPA at Envirite Co.

Constituent/parameter	Concentration (ppm)							
	Sample Set #1		Sample Set #2		Sample Set #3		Sample Set #4	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals								
Antimony	<10	<1	<10	<1	<10	<1	<10	-
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Barium	<10	<1	<10	<1	<10	3.5	<10	<10
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<2
Cadmium	13	<0.5	10	<0.5	<5	<0.5	<5	<5
Chromium (hexavalent)	893	0.011	807	0.190	775	-[a]	0.6	0.042
Chromium (total)	2,581	0.12	2,279	0.12	1,990	0.20	556	0.10
Copper	138	0.21	133	0.15	133	0.21	88	0.07
Lead	64	<0.01	54	<0.01	<10	<0.01	<10	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Nickel	471	0.33	470	0.33	16,330	0.33	6,610	0.33
Selenium	<10	<1	<10	<1	<10	<1	<10	<10
Silver	<2	<0.2	2	<0.2	<2	<0.3	<2	<2
Thallium	<10	<1	<10	<1	<10	<1	<10	<10
Zinc	116	0.125	4	0.115	3.9	0.140	84	1.62
Other Parameters								
Total organic carbon	2700		2800		500		2900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	2500		3600		0		900	

Table 4-14 (continued)

	Concentration (ppm)							
	Sample Set #5		Sample Set #6		Sample Set #7		Sample Set #8	
Constituent/parameter	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals								
Antimony	<10	<1	<10	<1	<10	<1	<10	<1
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<0.1
Barium	<10	<1	<10	<2	<10	<1	<10	<1
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Cadmium	<5	<0.5	<5	<0.5	10	<0.5	<5	<0.5
Chromium (hexavalent)	917	0.058	734	-[a]	769	0.121	0.13	<0.01
Chromium (total)	2,236	0.11	2,548	0.10	2,314	0.12	831	0.15
Copper	91	0.14	149	0.12	72	0.16	217	0.16
Lead	18	<0.01	<10	<0.01	108	<0.01	212	<0.01
Mercury	1	<0.1	<1	<0.1	<1	<0.01	<1	<0.1
Nickel	1,414	0.310	588	0.33	426	0.40	669	0.36
Selenium	<10	<1	<10	<1	<10	<1	<10	<1
Silver	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1	<10	<1	<10	<1	<10	<1
Zinc	71	0.125	4	0.095	171	0.115	151	0.130
Other Parameters								
Total organic carbon	200		700		3400		5900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	0		700		1900		800	

Table 4-14 (continued)

Constituent/parameter	Concentration (ppm)					
	Sample Set #9		Sample Set #10		Sample Set #11	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals						
Antimony	<10	<1	<10	<1	<10	<1.00
Arsenic	<1	<0.1	<1	<0.1	<1	<0.10
Barium	<10	<1	<10	<1	<12	<1.00
Beryllium	<2	<0.2	<2	<0.2	<2	<0.20
Cadmium	<5	<0.5	<5	<0.5	23	<5
Chromium (hexavalent)	0.07	0.041	0.08	0.106	0.30	<0.01
Chromium (total)	939	0.10	395	0.12	617	0.18
Copper	225	0.08	191	0.14	137	0.24
Lead	<10	<0.01	<10	<0.01	136	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.10
Nickel	940	0.33	712	0.33	382	0.39
Selenium	<10	<1.0	<10	<1	<10	<1.00
Silver	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1.0	<10	<1	<10	<1.00
Zinc	5	0.06	5	0.070	135	0.100
Other Parameters						
Total organic carbon	2100		0		52	
Total solids	-		-		-	
Total chlorides	-		-		-	
Total organic halides	0		<300		300	

- = Not analyzed.

[a] Hexavalent chromium was actually treated by chromium reduction prior to chemical precipitation and sludge filtration.

Note: Design and Operating Parameters are as follows:

pH during chromium reduction - 8.5 to 9.0.

Reducing agent - ferrous iron.

Ratio of reducing agent to hexavalent chromium - 3.2 to 10.

pH during chemical precipitation - 8 to 10.

Precipitation agents - lime and sulfide.

Filter type - vacuum filter.

Reference: USEPA 1986a.

Table 4-15 Performance Data for Untreated and Treated F006 Wastes by Stabilization

Source	Mix ratio[a]	Metal concentrations (ppm)										
		Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Unknown												
Unstabilized												
As received		-	36.4	1.3	1270	40.2	35.5	-	435	-	2.3	1560
TCLP		<0.01	0.08	0.01	0.34	0.15	0.26	<0.001	0.71	<0.01	0.01	0.16
Stabilized												
TCLP	0.2	<0.01	0.12	0.01	0.51	0.20	0.30	<0.001	0.04	0.06	0.03	0.03
Auto part manufacturing												
Unstabilized												
As received		-	21.6	31.3	755	7030	409	-	989	-	6.62	4020
TCLP		<0.01	0.32	2.21	0.76	368	10.7	<0.001	22.7	<0.01	0.14	219
Stabilized												
TCLP	0.2	<0.01	0.50	0.50	0.40	5.4	0.40	<0.001	1.5	0.06	0.03	36.9
TCLP	0.5	<0.01	0.42	0.01	0.39	0.25	0.36	<0.001	0.03	0.11	0.05	0.01
Aircraft overhauling												
Unstabilized												
As received		-	85.5	67.3	716	693	25.7	-	259	-	39	631
TCLP		0.01	1.41	1.13	0.43	1.33	0.26	<0.001	1.1	<0.01	0.02	5.41
Stabilized												
TCLP	0.2	<0.01	0.33	0.06	0.08	1.64	0.30	<0.001	0.23	0.07	0.20	0.05
TCLP	0.5	<0.01	0.31	0.02	0.20	1.84	0.41	<0.001	0.15	0.11	0.05	0.03
Aerospace manufacturing (F006 & F007 mixture)												
Unstabilized												
As received		-	0.74	1.69	12.9	18.6	11.4	-	234	-	6.26	8.86
TCLP		<0.01	0.83	0.66	7.58	4.12	6.86	0.003	158	<0.01	1.64	2.28
Stabilized												
TCLP	1.0	<0.01	0.52	<0.01	0.40	0.23	0.20	<0.001	4.35	0.17	0.09	0.05
TCLP	1.5	<0.01	1.18	0.01	0.34	0.19	0.36	<0.001	2.47	0.20	0.15	0.03

Table 4-15 (continued)

Source	Mix ratio[a]	Metal concentrations (ppm)										
		Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Zinc plating												
Unstabilized												
As received		-	17.2	1.30	110	1510	88.5		37	-	9.05	90200
TCLP		-	0.84	0.22	0.18	4.6	0.45	<0.001	0.52	-	0.16	2030
Stabilized												
TCLP	0.2	<0.01	0.20	0.01	0.23	0.30	0.30	<0.001	0.10	0.08	0.03	32
TCLP	0.5	<0.01	0.23	0.01	0.30	0.27	0.34	<0.001	0.02	0.14	0.04	0.04
Unknown												
Unstabilized												
As received		-	14.3	720	12200	160	52	-	701	-	5.28	35900
TCLP		<0.01	0.38	23.6	25.3	1.14	0.45	<0.001	9.78	<0.01	0.08	867
Stabilized												
TCLP	0.2	<0.01	0.31	3.23	0.25	0.20	0.24	<0.001	0.53	0.04	0.04	3.4
TCLP	0.5	<0.01	0.19	0.01	0.38	0.29	0.36	<0.001	0.04	0.09	0.06	0.03
Small engine manufacturing												
Unstabilized												
As received		-	24.5	7.28	3100	1220	113	-	19400	-	4.08	27800
TCLP		<0.01	0.07	0.3	38.7	31.7	3.37	0.003	730	<0.01	0.12	1200
Stabilized												
TCLP	0.2	<0.01	0.30	0.02	0.21	0.21	0.30	<0.001	16.5	0.05	0.03	36.3
TCLP	0.5	<0.01	0.33	0.01	0.76	0.20	0.36	<0.001	0.05	0.11	0.05	0.04
Circuit board manufacturing												
Unstabilized												
As received		-	12.6	5.39	42900	10600	156	-	13000	-	12.5	120
TCLP		<0.01	0.04	0.06	360	8.69	1.0	<0.001	152	<0.01	0.05	0.62
Stabilized												
TCLP	0.2	<0.01	0.04	0.01	3.0	0.40	0.30	<0.001	0.40	0.04	0.03	0.02
TCLP	0.5	<0.01	0.14	0.01	1.21	0.42	0.38	<0.001	0.10	0.07	0.05	0.02

Table 4-15 (continued)

Source	Mix ratio[a]	Metal concentrations (ppm)										
		Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Unknown												
Unstabilized												
As received		-	15.3	5.81	47.9	17600	169	-	23700	-	8.11	15700
TCLP		<0.01	0.53	0.18	0.04	483	4.22	<0.001	644	<0.01	0.31	650
Stabilized												
TCLP	0.2	<0.01	0.32	0.01	0.10	0.50	0.31	<0.001	15.7	0.07	0.03	4.54
TCLP	0.5	<0.01	0.27	0.01	0.2	0.32	0.37	<0.001	0.04	0.07	0.05	0.02
Unknown												
Unstabilized												
As received		-	19.2	5.04	644	27400	24500	-	5730	-	19.1	322
TCLP		0.88	0.28	0.01	0.01	16.9	50.2	<0.001	16.1	<0.45	<0.01	1.29
Stabilized												
TCLP	0.2	<0.02	0.19	<0.01	0.03	3.18	2.39	<0.001	1.09	<0.01	<0.01	0.07
TCLP	0.5	<0.02	0.08	<0.01	0.21	0.46	0.27	<0.001	0.02	<0.01	<0.01	<0.01

[a] $\text{Mix ratio} = \frac{\text{weight of reagent}}{\text{weight of waste}}$

Source: CWM 1987.

5. IDENTIFICATION OF THE BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the rationale for the determination of best demonstrated available technology (BDAT) for K001 organics and metals treatment. As discussed in Section 1, the Agency examines all the available data for the demonstrated technologies to determine whether one of the technologies performs significantly better than the others. Next, the "best" performing treatment technology is evaluated to determine whether the resulting treatment is substantial. If the "best" technology is "available", (i.e., (1) it provides substantial treatment and (2) EPA has determined that the technology is commercially available to the affected industry), then the technology represents BDAT.

5.1 BDAT for Treatment of Organic Constituents

For treatment of organics in K001, the Agency has data only from rotary kiln incineration. The data were collected during two treatment tests in which the K001 wastes were incinerated in two separate rotary kiln units. Because data from the other demonstrated technologies are not available, the Agency cannot compare performance to determine which technology is "best." However, the Agency would not expect the level of performance to be improved by other forms of incineration such as fluidized bed or fixed hearth because rotary kiln incineration destroyed all BDAT list organics to concentrations below their detection limits. In addition, EPA believes that well-designed and well-operated fuel substitution systems could not achieve better treatment since they operate at approximately the same temperatures and turbulent conditions as incineration systems.

Consistent with EPA's methodology for determining BDAT, the Agency evaluated the rotary kiln incineration performance data to determine whether the technology provides substantial treatment for BDAT list organic constituents in K001.

As a first step in determining whether substantial treatment is provided, the available treatment data described in Section 4 were reviewed and assessed with regard to the design and operation of the treatment systems, the analytical testing, and the quality assurance/ quality control analyses of the data. In general, all of the performance data collected for rotary kiln incineration of K001 were of sufficient quality for the determination of substantial treatment. Design and operating data were collected for the rotary kiln incineration systems used for destroying BDAT list organic constituents in K001 wastes. These data indicate that the systems were well designed and well operated during the test burns. In addition, the proper analytical tests were performed for the untreated wastes and the treated residuals. Specifically, because incineration is a destruction technology for organics, total constituent concentration of organics is used to measure treatment performance.

Next, EPA adjusted the data values based on the analytical recovery values to take into account analytical interferences associated with the chemical makeup of the treated sample. In summary, EPA first analyzes a waste for a constituent and then adds a known amount of the same constituent (i.e., spike) to the waste material. The total amount recovered after spiking minus the initial concentration in the sample, all divided by the amount added, is the recovery value. The reciprocal of the recovery value (EPA uses the lower value of the matrix spike and matrix duplicate recoveries, in general), multiplied by the performance data value, is the accuracy-corrected value used in comparing treatment and subsequently in calculating treatment standards. Percent recovery values for the BDAT list constituents in the K001 performance data are presented in Appendix B. (The methodology for adjusting the performance data is discussed in Section 1.)

EPA's determination that substantial treatment occurs is based on the reduction of BDAT list organic constituents from levels as high as 43,000 ppm to nondetectable levels (i.e., 0.010 ppm) in the scrubber water and ash residuals. In addition to the substantial reduction, rotary kiln incineration is commercially available; therefore, rotary kiln incineration meets the second criteria for "availability." As "best," "demonstrated," and "available," the technology represents BDAT for the organics present in K001.

5.2 BDAT for Treatment of Metal Constituents

Treatment of the organics present in K001 using rotary kiln incineration generates a nonwastewater and a wastewater residual that require treatment for BDAT list metals. Treatment of the scrubber water may also generate a precipitate (i.e., nonwastewater residual) that also may require treatment for BDAT list metals. The performance data for the BDAT list metals detected in the treated residuals from incineration of K001 were examined to determine whether substantial treatment had occurred.

5.2.1 Wastewater

The only demonstrated technology identified for treatment of metals in K001 scrubber water for which the Agency has data is chemical precipitation followed by filtration. As discussed earlier, EPA does not have treatment data for K001 wastewaters generated from rotary kiln incineration; however, EPA does have treatment data specifically for metal-containing wastewaters (Envirite) believed to be similar to K001 scrubber water.

EPA's determination of substantial wastewater treatment for the Envirite treatment system is based on the reductions of hexavalent chromium from 917 mg/l to 0.058 mg/l, chromium from 2,581 mg/l to 0.12 mg/l, lead from 212 mg/l to 0.01 mg/l, copper from 225 mg/l to 0.08 mg/l, nickel from 16,330 mg/l to 0.33 mg/l, and zinc from 171 mg/l to 0.115 mg/l. The treated concentrations are accuracy-corrected values adjusted in the same manner described for the organic constituents. Since the operating data collected during treatment of this waste show that these data represent the performance of a well-desiged, well-operated treatment system, all data were used in determining substantial treatment.

The Agency has no reason to expect that the use of other processes could improve the level of performance; therefore, chemical precipitation followed by sludge filtration is "best." Chemical precipitation, followed by sludge filtration, is "available" because the components of the treatment system are commercially available and the treatment provides substantial treatment. Therefore, the treatment system consisting of chemical precipitation followed by sludge filtration represents BDAT for BDAT list metals in K001 wastewaters.

5.2.2 Nonwastewater

In determining whether stabilization provides "substantial" treatment, EPA first evaluated the data base (shown in Section 4) to determine if any data should be deleted because the data are generated from treatment of wastes determined to be less representative of F006 than other wastes for which EPA has treatment data. EPA's review of the data showed that waste from the aerospace manufacturing industry contained both F006 and F007 wastes. EPA deleted these data from consideration because the Agency had other data on treatment of F006 wastes alone and because EPA had no information as to the percentage of F006 and F007 in the aerospace industry waste.

EPA's assessment of "substantial" treatment also included review of the data to determine whether any data should be deleted because they could be shown to not represent a well-designed and well-operated system. EPA reviewed the treatment data associated with each mix ratio (binder-to-waste ratio) and deleted data from the less effective binder-to-waste ratio; this process resulted in deletion of 99 treated data points (see Table C-2 in Appendix C for specific constituents deleted). Other data were deleted for individual constituents for one of the following reasons: (1) the treated waste concentration was higher than the untreated waste concentration, (2) insufficient information was present on the untreated constituent to determine treatment effectiveness; (3) the untreated leachate concentration was already at a low level, where meaningful treatment could not be determined; and (4) the treated level of performance could be attributed solely to dilution from the binder. The specific constituents deleted for each rationale are shown in Table F-1 in Appendix F.

The performance data that EPA used in assessing "substantial" treatment are shown in Table 5-1. As shown, stabilization achieved reductions in the leachate value for the metal selected for regulation. (Section 6 presents a detailed discussion of constituents selected for regulation.) Specifically, leachate reductions for lead were from as high as 50.2 mg/l in the untreated waste to 0.29 mg/l in the treated residual. Other substantial reductions were as high as 358 mg/l for chromium, 729 mg/l for nickel, and 2030 mg/l for zinc.

The Agency believes the reduction in the range and magnitude of the various BDAT list metal constituents to be substantial. Stabilization has been determined to be demonstrated and best, has provided substantial treatment, and is commercially available; therefore, stabilization represents BDAT for K001 nonwastewaters.

Table 5-1 Accuracy-Corrected Performance Data for Untreated and Treated F006 Wastes by Stabilization

Source	Mix ratio[a]	Metal concentrations (ppm)							
		Barium	Cadmium	Chromium	Copper	Lead	Nickel	Silver	Zinc
Unknown									
Unstabilized									
As received		-	-	-	-	-	435	-	1560
TCLP		-	-	-	-	-	0.71	-	0.16
Stabilized									
TCLP	0.2	-	-	-	-	-	0.05	-	0.03
Auto part manufacturing									
Unstabilized									
As received		-	31.3	755	7030	409	989	6.62	4020
TCLP		-	2.21	0.76	638	10.7	22.7	0.14	219
Stabilized									
TCLP	0.5	-	0.01	0.45	0.27	0.39	0.03	0.06	0.01
Aircraft overhauling									
Unstabilized									
As received		85.5	67.3	716	-	-	259	-	631
TCLP		1.41	1.13	0.43	-	-	1.1	-	5.41
Stabilized									
TCLP	0.2	0.34	0.06	0.09	-	-	0.27	-	0.03
Zinc plating									
Unstabilized									
As received		17.2	1.30	-	1510	-	37	9.05	90,200
TCLP		0.84	0.22	-	4.6	-	0.52	0.16	2050
Stabilized									
TCLP	0.5	0.25	0.01	-	0.21	-	0.02	0.05	0.04
Unknown									
Unstabilized									
As received		14.3	720	12,200	160	-	701	-	25,900
TCLP		0.38	23.6	25.3	1.14	-	9.78	-	867
Stabilized									
TCLP	0.5	0.21	0.01	0.44	0.31	-	0.04	-	0.03

Table 5-1 (continued)

Source	Mix ratio[a]	Metal concentrations (ppm)							
		Barium	Cadmium	Chromium	Copper	Lead	Nickel	Silver	Zinc
Small engine manufacturing									
Unstabilized									
As received		-	7.28	3,100	1220	113	19,400	4.08	27,800
TCLP		-	0.3	38.7	31.7	3.37	730	0.12	1200
Stabilized									
TCLP	0.5	-	0.01	0.89	0.31	0.39	0.06	0.06	0.040
Circuit board manufacturing									
Unstabilized									
As received		-	5.39	42,900	10,600	156	13,000	-	120
TCLP		-	0.06	360	8.69	1.0	152	-	0.62
Stabilized									
TCLP	0.5	-	0.01	1.41	0.45	0.41	0.11	-	0.020
Unknown									
Unstabilized									
As received		15.3	5.81	-	17,600	169	23,700	8.11	15,700
TCLP		0.53	0.18	-	483	4.22	644	0.31	650
Stabilized									
TCLP	0.5	0.294	0.01	-	0.35	0.40	0.04	0.06	0.020
Unknown									
Unstabilized									
As received		19.2	-	-	27,400	24,500	5,730	-	322
TCLP	-	0.28	-	-	16.9	50.2	16.1	-	1.29
Stabilized									
TCLP	0.5	0.087	-	-	0.50	0.29	<0.02	-	<0.01

[a] Mix ratio = $\frac{\text{weight of reagent}}{\text{weight of waste}}$

Reference: CWM 1987.

6. SELECTION OF REGULATED CONSTITUENTS

As discussed in Section 1, the Agency has developed a list of hazardous constituents (Table 1-1) from which the constituents to be regulated are selected. EPA may revise this list as additional data and information become available. The list is divided into the following categories: volatile organics, semivolatile organics, metals, inorganics other than metals, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorus insecticides, PCBs, and dioxins and furans.

This section presents the rationale for selection of the regulated constituents, from the BDAT list of constituents, for K001. The process involves developing a list of potential regulated constituents and then eliminating those constituents that would not be treated by the chosen BDAT or that would be controlled by regulation of the remaining constituents.

6.1 Identification of BDAT List Constituents in Untreated K001

As discussed in Sections 2 and 4, the Agency has characterization data as well as performance data from treatment of K001 waste. These data, as well as information on the waste generating processes, have been used to determine which BDAT list constituents may be present in the waste and thus which are potential candidates for regulation in nonwastewater and wastewater forms of K001.

Table 6-1, at the end of this section, indicates, for the untreated waste, which constituents were analyzed and which constituents were detected. For those constituents detected, concentrations are indicated. Of the 232 constituents on the BDAT list, 218 were analyzed and 31 were detected.

Constituents may not have been detected in the untreated waste for one of several reasons: (1) none of the untreated waste samples were analyzed for those constituents, (2) masking or interference by other constituents prevented detection, or (3) the constituent indeed was not present.

6.2 Determination of Significant Treatment from BDAT

The next step in selecting the constituents to be regulated is to eliminate those identified constituents in the waste that cannot be significantly treated by the technologies designated as BDAT.

6.2.1 BDAT List Organic Constituents

Tables 6-2 and 6-3 present the concentrations of BDAT list constituents in the untreated K001 waste and the treatment residuals from rotary kiln incineration, i.e., scrubber water and ash. The data demonstrate that all the organic constituents detected in untreated K001 are reduced significantly. Specifically, all BDAT list volatile and semivolatile constituents detected in the untreated waste were reduced to concentrations below their detection limits by rotary kiln incineration. Because all of the BDAT list volatiles and semivolatile constituents detected in the untreated waste were reduced to concentrations below their detection limits by rotary kiln incineration, these compounds were regarded as potential regulated constituents, as they were significantly treated by incineration.

6.2.2 BDAT List Metal Constituents

The K001 incineration data show a scrubber water with no treatable levels of organics, but treatable amounts of BDAT list metals. Rotary kiln incineration is not designed to treat metals; however, metal constituents present in the untreated waste will be present in the incinerator ash and scrubber water treatment residuals. In this case of K001 as tested by the Agency, the BDAT list metal constituents present in the highest concentration in the untreated waste were also among the constituents most prevalent in both wastewaters and nonwastewater residuals. These constituents included barium, copper, lead, and zinc, which were therefore considered as regulated constituents.

For the K001 scrubber waters, zinc and lead were generally present in the highest concentrations. Several other BDAT list metals including barium, copper, and thallium were also present. EPA examined available treatment performance data for chemical precipitation and filtration for which design and operating data were available. The performance data identified from the Agency's testing at Envirite did not indicate treatment of thallium or barium in wastewaters.

Treatment of the metals present in the Envirite wastewaters is demonstrated by the significant reduction of cadmium, hexavalent chromium, chromium, copper, lead, nickel, and zinc in the filtrate. However, the untreated Envirite wastewaters do not contain detectable levels of antimony, arsenic, barium, silver, and vanadium. Therefore, even though these metals may be present in quantities below the detection levels, one cannot determine whether these metals were treated since the amounts present cannot be measured. However, these data for chemical precipitation and filtration did show substantial reduction for lead.

All stabilization data from wastes similar to K001 nonwastewaters were examined. Stabilization performance data for F006 showed substantial treatment for lead. Specifically, the TCLP values for lead were reduced from as high as 50.2 ppm in the untreated waste to as low as 0.29 ppm in the stabilized residual.

6.3 Selection of Regulated Constituents

6.3.1 BDAT List Organic Constituents

As explained in Section 1, the Agency is not proposing to regulate all of the BDAT list constituents considered for regulation. As stated previously, all of the BDAT list organics detected in the untreated waste were reduced to concentrations below their detection limits in the ash and scrubber water, and therefore were considered for regulation. In general, the Agency has considered whether some constituents are adequately controlled by the regulation of another constituent.

For organic constituents, determination of adequate control was based on an evaluation of the characteristics of the constituents that would affect treatment performance of rotary kiln incineration. Specifically, the waste characteristics affecting performance, as explained in the incineration discussion in Section 3.2.1, include the volatility (boiling point) and bond dissociation energies of the constituents of a waste. Consistent with the theory of combustion, constituents having higher boiling points and higher bond dissociation energies are the most difficult to destroy. Also, BDAT list organic constituents present in the untreated waste in the highest concentrations are believed to be among the constituents that are most difficult to treat to nondetectable levels.

For K001 organic treatment by rotary kiln incineration, the constituents proposed for regulation are naphthalene, pentachlorophenol, phenathrene, pyrene, toluene, and xylene (total). These constituents were selected because they are indicators of effective treatment and it is believed that other BDAT list organics will be treated to levels equivalent to or lower than these constituents. In general, these constituents are present in the untreated waste in the highest concentrations, have high bond dissociation energies, and/or have high boiling points. Table C-1 in Appendix C contains a ranking of the BDAT list organic constituents detected in K001 based on concentration, boiling point, and bond dissociation energy. Specifically, these constituents were selected for the following reasons:

1. Naphthalene - BDAT list constituent present in the untreated waste in the highest concentration.
2. Pentachlorophenol - Highly chlorinated constituent that will serve as indicator for all chlorinated BDAT list organics.
3. Phenanthrene - BDAT list constituent present in the untreated waste in the highest concentration second to naphthalene, with moderate boiling point and bond dissociation energy.
4. Pyrene - BDAT list semivolatile with bond dissociation energy among the highest of any BDAT list semivolatile organic, high boiling point, and present in higher concentrations than other constituents with comparable bond dissociation energies and boiling points.

5. Toluene - BDAT list volatile organic constituent present in highest concentration.
6. Xylene - BDAT list volatile constituent present in untreated waste with highest bond dissociation energy and boiling point and concentrations similar to toluene.

EPA believes that the other BDAT list organic constituents present in K001 wastes will be adequately controlled by rotary kiln incineration if these regulated constituents are controlled to concentrations below their detection limits.

6.3.2 BDAT List Metal Constituents

Several BDAT list metal constituents were detected in the untreated waste collected by the Agency, with barium, copper, lead, and zinc being present in the highest concentrations. Generally, the metals present in the highest concentrations in the untreated waste are also present in the residuals from rotary kiln incineration (scrubber water and ash) at the highest concentrations. Whether a BDAT list metal constituent present in the untreated waste will be detected in the ash or the scrubber waste will depend on the volatility of the constituent and the operating temperature of the rotary kiln incinerator.

For BDAT list metals present in the scrubber water from incineration of K001, lead is the regulated constituent. The Agency has no data that demonstrate that other BDAT list metals will not be adequately controlled by the regulation of lead because the others are typically present at lower concentrations.

For BDAT list metals in nonwastewater forms of K001 such as incinerator ash or filter cake from the treatment of scrubber water by chemical precipitation and sludge filtration, lead is also being regulated. The Agency has no treatment performance data showing that the regulation of lead will not adequately ensure control of other BDAT list metals present in wastewater forms of K001.

Table 6-1 Status of BDAT List Constituent Presence in Untreated K001

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Volatile organics		
222.	Acetone	ND	
1.	Acetonitrile	ND	
2.	Acrolein	ND	
3.	Acrylonitrile	ND	
4.	Benzene	51-83	
5.	Bromodichloromethane	ND	
6.	Bromomethane	ND	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	ND	
8.	Carbon disulfide	ND	
9.	Chlorobenzene	ND	
10.	2-Chloro-1,3-butadiene	ND	
11.	Chlorodibromomethane	ND	
12.	Chloroethane	ND	
13.	2-Chloroethyl vinyl ether	ND	
14.	Chloroform	ND	
15.	Chloromethane	ND	
16.	3-Chloropropene	ND	
17.	1,2-Dibromo-3-chloropropane	ND	
18.	1,2-Dibromoethane	ND	
19.	Dibromomethane	ND	
20.	trans-1,4-Dichloro-2-butene	ND	
21.	Dichlorodifluoromethane	ND	
22.	1,1-Dichloroethane	ND	
23.	1,2-Dichloroethane	ND	
24.	1,1-Dichloroethylene	ND	
25.	trans-1,2-Dichloroethene	ND	
26.	1,2-Dichloropropane	ND	
27.	trans-1,3-Dichloropropene	ND	
28.	cis-1,3-Dichloropropene	ND	
29.	1,4-Dioxane	ND	
224.	2-Ethoxyethanol	NA	
225.	Ethyl acetate	ND	
226.	Ethyl benzene	55-87	
30.	Ethyl cyanide	ND	
227.	Ethyl ether	ND	
31.	Ethyl methacrylate	ND	
214.	Ethylene oxide	ND	
32.	Iodomethane	ND	
33.	Isobutyl alcohol	ND	
228.	Methanol	NA	
34.	Methyl ethyl ketone	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Volatile organics (continued)		
229.	Methyl isobutyl ketone	ND	
35.	Methyl methacrylate	ND	
37.	Methacrylonitrile	ND	
38.	Methylene chloride	ND	
230.	2-Nitropropane	NA	
39.	Pyridine	ND	
40.	1,1,1,2-Tetrachloroethane	ND	
41.	1,1,2,2-Tetrachloroethane	ND	
42.	Tetrachloroethene	ND	
43.	Toluene	10-170	
44.	Tribromomethane	ND	
45.	1,1,1-Trichloroethane	ND	
46.	1,1,2-Trichloroethane	ND	
47.	Trichloroethene	ND	
48.	Trichloromonofluoromethane	ND	
49.	1,2,3-Trichloropropane	ND	
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	
50.	Vinyl chloride	ND	
215.	1,2-Xylene	120-170[b]	
216.	1,3-Xylene	120-170[b]	
217.	1,4-Xylene	120-170[b]	
	Semivolatile organics		
51.	Acenaphthalene	1,000-4,600	
52.	Acenaphthene	13,000-21,000	
53.	Acetophenone	ND	
54.	2-Acetylaminofluorene	ND	
55.	4-Aminobiphenyl	ND	
56.	Aniline	ND	
57.	Anthracene	8,500-15,000	
58.	Aramite	ND	
59.	Benz(a)anthracene	<2,500-3,400	
218.	Benzal chloride	NA	
60.	Benzenethiol	ND	
61.	Deleted		
62.	Benzo(a)pyrene	<250-940	
63.	Benzo(b)fluoranthene	940-2,300[c]	
64.	Benzo(ghi)perylene	ND	
65.	Benzo(k)fluoranthene	940-2,300[c]	
66.	p-Benzoquinone	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Semivolatile organics (continued)		
67.	Bis(2-chloroethoxy)methane	ND	
68.	Bis(2-chloroethyl)ether	ND	
69.	Bis(2-chloroisopropyl)ether	ND	
70.	Bis(2-ethylhexyl)phthalate	ND	
71.	4-Bromophenyl phenyl ether	ND	
72.	Butyl benzyl phthalate	ND	
73.	2-sec-Butyl-4,6-dinitrophenol	NA	
74.	p-Chloroaniline	ND	
75.	Chlorobenzilate	ND	
76.	p-Chloro-m-cresol	ND	
77.	2-Chloronaphthalene	ND	
78.	2-Chlorophenol	ND	
79.	3-Chloropropionitrile	NA	
80.	Chrysene	<2,500-4,800	
81.	ortho-Cresol	ND	
82.	para-Cresol	ND	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	ND	
84.	Dibenzo(a,e)pyrene	ND	
85.	Dibenzo(a,i)pyrene	ND	
86.	m-Dichlorobenzene	ND	
87.	o-Dichlorobenzene	ND	
88.	p-Dichlorobenzene	ND	
89.	3,3'-Dichlorobenzidine	ND	
90.	2,4-Dichlorophenol	ND	
91.	2,6-Dichlorophenol	ND	
92.	Diethyl phthalate	ND	
93.	3,3'-Dimethoxybenzidine	ND	
94.	p-Dimethylaminoazobenzene	ND	
95.	3,3'-Dimethylbenzidine	ND	
96.	2,4-Dimethylphenol	ND	
97.	Dimethyl phthalate	ND	
98.	Di-n-butyl phthalate	ND	
99.	1,4-Dinitrobenzene	ND	
100.	4,6-Dinitro-o-cresol	ND	
101.	2,4-Dinitrophenol	ND	
102.	2,4-Dinitrotoluene	ND	
103.	2,6-Dinitrotoluene	ND	
104.	Di-n-octyl phthalate	ND	
105.	Di-n-propylnitrosamine	ND	
106.	Diphenylamine	ND	
219.	Diphenylnitrosamine	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Semivolatile organics (continued)		
107.	1,2-Diphenylhydrazine	ND	
108.	Fluoranthene	13,000-21,000	
109.	Fluorene	8,200-18,000	
110.	Hexachlorobenzene	ND	
111.	Hexachlorobutadiene	ND	
112.	Hexachlorocyclopentadiene	ND	
113.	Hexachloroethane	ND	
114.	Hexachlorophene	NA	
115.	Hexachloropropene	ND	
116.	Indeno(i,2,3-cd)pyrene	ND	
117.	Isosafrole	ND	
118.	Methapyrilene	ND	
119.	3-Methylcholanthrene	ND	
120.	4,4'-Methylenebis (2-chloroaniline)	ND	
36.	Methyl methanesulfonate	NA	
121.	Naphthalene	26,000-43,000	
122.	1,4-Naphthoquinone	ND	
123.	1-Naphthylamine	ND	
124.	2-Naphthylamine	ND	
125.	p-Nitroaniline	ND	
126.	Nitrobenzene	ND	
127.	4-Nitrophenol	ND	
128.	N-Nitrosodi-n-butylamine	ND	
129.	N-Nitrosodiethylamine	ND	
130.	N-Nitrosodimethylamine	ND	
131.	N-Nitrosomethylethylamine	ND	
132.	N-Nitrosomorpholine	ND	
133.	N-Nitrosopiperidine	ND	
134.	n-Nitrosopyrrolidine	ND	
135.	5-Nitro-o-toluidine	ND	
136.	Pentachlorobenzene	ND	
137.	Pentachloroethane	ND	
138.	Pentachloronitrobenzene	ND	
139.	Pentachlorophenol	920	
140.	Phenacetin	ND	
141.	Phenanthrene	28,000-42,000	
142.	Phenol	2,400-3,900	
220.	Phthalic anhydride	NA	
143.	2-Picoline	ND	
144.	Pronamide	ND	
145.	Pyrene	9,200-17,000	
146.	Resorcinol	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Semivolatile organics (continued)		
147.	Safrole	ND	
148.	1,2,4,5-Tetrachlorobenzene	ND	
149.	2,3,4,6-Tetrachlorophenol	ND	
150.	1,2,4-Trichlorobenzene	ND	
151.	2,4,5-Trichlorophenol	ND	
152.	2,4,6-Trichlorophenol	ND	
153.	Tris(2,3-dibromopropyl) phosphate	NA	
	Metals		
154.	Antimony	ND	
155.	Arsenic	0.7-2.9	
156.	Barium	12-150	
157.	Beryllium	ND	
158.	Cadmium	0.4-3.55	
159.	Chromium (total)	1.5-8.6	
221.	Chromium (hexavalent)	NA	
160.	Copper	6.7-39	
161.	Lead	6.3-190	
162.	Mercury	0.0064-1.64	
163.	Nickel	1.8-7.5	
164.	Selenium	0.3-1.5	
165.	Silver	ND	
166.	Thallium	2.2-8.0	
167.	Vanadium	0.82-4.0	
168.	Zinc	30-200	
	Inorganics other than metals		
169.	Cyanide	ND	
170.	Fluoride	0.95	
171.	Sulfide	0.51	
	Organochlorine pesticides		
172.	Aldrin	ND	
173.	alpha-BHC	ND	
174.	beta-BHC	ND	
175.	delta-BHC	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Organochlorine pesticides (continued)		
176.	gamma-BHC	ND	
177.	Chlordane	ND	
178.	DDD	ND	
179.	DDE	ND	
180.	DDT	ND	
181.	Dieldrin	ND	
182.	Endosulfan I	ND	
183.	Endosulfan II	ND	
184.	Endrin	ND	
185.	Endrin aldehyde	ND	
186.	Heptachlor	ND	
187.	Heptachlor epoxide	ND	
188.	Isodrin	ND	
189.	Kepone	ND	
190.	Methoxyclor	ND	
191.	Toxaphene	ND	
	Phenoxyacetic acid herbicides		
192.	2,4-Dichlorophenoxyacetic acid	ND	
193.	Silvex	ND	
194.	2,4,5-T	ND	
	Organophosphorous insecticides		
195.	Disulfoton	ND	
196.	Famphur	ND	
197.	Methyl parathion	ND	
198.	Parathion	ND	
199.	Phorate	ND	
	PCBs		
200.	Aroclor 1016	ND	
201.	Aroclor 1221	ND	
202.	Aroclor 1232	ND	
203.	Aroclor 1242	ND	
204.	Aroclor 1248	ND	
205.	Aroclor 1254	ND	
206.	Aroclor 1260	ND	

Table 6-1 (continued)

BDAT reference no.	Constituent	Detection status	Believed to be present[a]
	Dioxins and furans		
207.	Hexachlorodibenzo-p-dioxins	ND	
208.	Hexachlorodibenzofurans	ND	
209.	Pentachlorodibenzo-p-dioxins	ND	
210.	Pentachlorodibenzofurans	ND	
211.	Tetrachlorodibenzo-p-dioxins	ND	
212.	Tetrachlorodibenzofurans	ND	
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND[d]	

D = Detected in untreated waste samples.
ND = Not detected.
NA = Not analyzed.
X = Believed to be present based on engineering analysis of waste generating process.
Y = Believed to be present based on detection in treated residuals.

[a] No constituents were detected or believed to be present in the untreated waste.

[b] Xylene isomers were not differentiated during analysis.

[c] Analyzed as benzo(b and/or k)fluoranthene

[d] Dioxin analyses were not isomer specific; therefore, 2,3,7,8-TCDD was not quantified separately from all TCDD.

Table 6-2 BDAT List Constituents Detected in Untreated
K001-Creosote and Treatment Residuals

BDAT list constituent	Range of concentrations (ppm)		
	Untreated waste (mg/kg)	ash (mg/kg)	scrubber water (mg/l)
Volatiles			
Benzene	51- 83	<0.050	<0.050
Toluene	100-170	<0.050	<0.050
Ethyl Benzene	55- 87	<0.050	<0.050
Xylenes	120-170	<0.050	<0.050
Semivolatiles			
Acenaphthalene	1,000-<4,600	<1.15	<0.020
Acenaphthene	15,000-21,000	<0.65	<0.010
Anthracene	7,300-15,000	<0.65	<0.010
Chrysene	4,100- 4,800	<0.85	<0.015
Fluorene	12,000-18,000	<0.65	<0.010
Naphthalene	29,000-43,000	<0.55	<0.010
Phenanthrene	29,000-41,000	<1.80	<0.030
Phenol	2,400- 3,900	<0.50	<0.010
Pyrene	12,000-17,000	<0.65	<0.010
Metals			
Arsenic	0.7 - 2.6	<0.02-<0.035	0.041-1.6
Barium	12 - 150	0.22- 0.57	0.56 -1.1
Cadmium	0.79- 3.5	<2.0	0.48 -1.2
Chromium	1.6 - 8.6	5.3 - 10	0.35 -1.0
Copper	12 - 39	86-130	0.35 -0.51
Lead	37 - 190	<2.1	2.5 - 5.4
Mercury	0.35- 1.64	<1.25	0.008-0.54
Nickel	1.8 - 7.5	3.6 - 6.8	0.48 -0.70
Selenium	0.3 - 1.5	1.8 - 2.8	0.021-1.2
Thallium	2.2 - 8.0	<2.5	<0.028-3.8
Vanadium	0.82- 4.0	4.1 - 5.2	0.040-0.080
Zinc	40 - 200	1.8 - 3.2	5.0 - 11

Table 6-3 BDAT List Constituents Detected in Untreated K001-PCP and Treatment Residuals

BDAT list constituent	Range of concentrations (ppm) Untreated waste (mg/kg)	ash (mg/kg)	scrubber water (mg/l)
Volatiles			
Toluene	10-39	<0.010	<0.010
Semivolatiles			
Acenaphthene	13,000-18,000	<2.5	<0.050
Anthracene	8,500-13,000	<2.5	<0.050
Benz(a)anthracene	<2,500- 3,400	<2.5	<0.010
Benzo(a)pyrene	<250- 940	<2.5	<0.050
Benzo(b and/or k) fluoranthrene	940- 2,300	<2.5	<0.050
Chrysene	<2,500- 3,600	<2.5	<0.050
Fluoranthene	13,000-21,000	<2.5	<0.050
Fluorene	8,200-12,000	<2.5	<0.050
Naphthalene	26,000-43,000	<2.5	<0.050
Pentachlorophenol	920- 3,000	<12.5	<0.020
Phenanthrene	28,000-42,000	<2.5	<0.050
Pyrene	9,200-15,000	<2.5	<0.050
Metals			
Arsenic	1.1 - 2.9	0.4 - 0.8	<0.01-0.12
Barium	17 - 30	21 - 74	<0.12-0.39
Cadmium	0.4 - 0.6	<1.5	<0.015
Chromium	1.5 - 2.7	1.1 - 8.2	<0.045
Copper	6.7 - 11	2 - 6.8	0.07-0.15
Lead	6.3 - 11	0.96 - 5.2	0.020-0.18
Mercury	0.0064 - 0.11	<0.001	<0.001-0.003
Zinc	30 - 64	2.1 - 11	0.61-1.1

7. CALCULATION OF BDAT TREATMENT STANDARDS

The purpose of this section is to present the calculation of the actual treatment standards, using analytical treatment data, for the regulated constituents selected in Section 6. EPA is setting treatment standards for K001 waste based on performance data from (1) rotary kiln incineration of K001 waste, (2) chemical precipitation and sludge filtration of a metal-bearing wastewater sampled by EPA, and (3) stabilization of F006 waste. As discussed in Section 1, the following steps are taken to derive the BDAT treatment standards:

1. The Agency evaluates the available data for the BDAT treatment technologies and deletes any data representing poor design or poor operation of the treatment systems.
2. Averages for accuracy-corrected constituent concentrations are calculated based on analytical QA/QC recovery data, and a variability factor is also determined for each constituent selected for regulation.
3. The BDAT treatment standard for each constituent selected for regulation is determined by multiplying the average accuracy-corrected total composition by the appropriate variability factor.

Using these three steps, the following sections present the calculation of the BDAT list organic and metal treatment standards for K001 nonwastewaters and wastewaters. Appendix B presents the quality assurance/quality control data used to calculate the accuracy-corrected values. The method for calculation of the variability factors is presented in Appendix A.

7.1 Editing the Data

7.1.1 BDAT List Organics Treatment

As discussed in Section 4, the Agency collected nine data sets for rotary kiln incineration of K001 waste at two separate test facilities. The Agency evaluated the nine data sets and determined that the treatment systems were well operated during the sampling periods. These data sets also included the appropriate analytical tests to evaluate treatment performance of incineration. Because incineration is a destruction technology for organics, total constituent concentration is the best measure of performance. The quality assurance/quality control data were also available for the BDAT list organics and metals, as previously discussed in detail in Section 4.

7.1.2 BDAT List Metals Treatment

Incineration of K001 results in the generation of two treatment residuals: ash (nonwastewater K001 residual) and scrubber water (wastewater K001 residual). Because the untreated K001 waste contains BDAT list metal constituents, these treatment residuals also contain metals at treatable concentrations. As discussed in Section 4, the Agency does not have treatment performance data specifically for BDAT list metals in the wastewater and nonwastewater forms of K001. However, EPA does have treatment performance data for wastes that the Agency believes are similar to these K001 residuals.

For the wastewater form of K001 (scrubber water), treatment performance data were available for the treatment system consisting of chemical precipitation and sludge filtration. Eleven data sets were available for treatment of metal-bearing wastewaters from the Onsite Engineering Report for Envirite Co. The design and operating data collected for this treatment system indicate that it was well designed and well operated during the time of sampling. In addition, the analytical testing data for total composition of BDAT list metals were the appropriate tests for this technology. However, recovery values were not available for metal spikes and metal spike duplicates from the treatment data transferred from the Onsite Engineering Report for Envirite Co. The recovery data were transferred from the Onsite Engineering Report for Horsehead Resource Development Co. for K061. This was done because lead is present in both wastes and the TCLP extracts from the treated K061 residual is a similar waste matrix to the wastewaters tested at Envirite and therefore the recoveries are expected to be similar.

For nonwastewater residuals containing BDAT list metals requiring stabilization, such as nonwastewater residuals from scrubber water treatment by chemical precipitation and filtration or incinerator ash, the Agency identified performance data from the treatment of F006. For treatment of BDAT list metals in K001 waste, the five data sets for lead in nonwastewaters from stabilization of F006, not deleted as the result of the criteria outlined in Section 5, reflect treatment in a well-designed, well-operated system; result from BDAT; and are accompanied by sufficient QA/QC data. Thus, they meet the requirements for setting treatment standards.

7.2 Correction of Analytical Data

The analytical data used to determine BDAT and calculate treatment standards were adjusted for accuracy to take into account the analytical interferences associated with the chemical composition of the sample. This was accomplished by calculating a correction factor from the percent recovery data for each regulated constituent. The accuracy-adjusted concentration was calculated by multiplying the uncorrected data value by the correction factor. The calculation of corrected data based on recoveries is detailed below for the regulated constituents.

7.2.1 Correction of BDAT List Organics Data

As previously discussed, the BDAT list organic constituents being regulated are naphthalene, pentachlorophenol, phenanthrene, pyrene, toluene, and xylene (total). All of these constituents were detected in the untreated K001 waste and were destroyed by rotary kiln incineration to concentrations below their detection limits in the nine data sets collected by the Agency. However, the detection limits attainable for these BDAT list organic constituents in the treatment residuals varied. Generally, where this occurred, the Agency selected the highest detection limit measured for each regulated constituent in each waste matrix (wastewater and nonwastewater). The treatment standards were developed using the higher detection limit because lower detection limits may not be consistently achievable. The treatment performance data for the regulated organics presented in this section, and used to calculate the treatment standards, reflect this change.

The recovery data used to develop accuracy-corrected data for BDAT list organics in K001 treatment residuals were from the accompanying matrix spike recoveries from the data with the higher detection limits. In one instance, it was necessary to transfer recovery data for pentachlorophenol in the scrubber water. The detection limit used to calculate the standard was from the treatment of the K001-pentachlorophenol waste, while the recovery data used were transferred from the matrix spike recovery performed for pentachlorophenol in the scrubber water from the K001-creosote waste. The accuracy correction factors used for all regulated organic constituents in both the wastewater and nonwastewater residuals are summarized in Table 7-1. The matrix spike recovery data used to correct the data used in calculating the treatment standards are presented in Appendix B.

7.2.2 Correction of BDAT List Metals Data

For K001 nonwastewater residuals the Agency is setting treatment standards for lead. As stated previously, the performance data for stabilization were transferred from F006 stabilization data. As a result, the matrix spike recovery values used to correct the data were developed with the analytical data for those F006 wastes. The correction factor used and the corrected values for lead in the nonwastewater residuals are presented in Table 7-2.

The Agency is also regulating lead in the K001 wastewater residual (scrubber water) from rotary kiln incineration. The treatment performance data for treatment by chemical precipitation and filtration were transferred from the Onsite Engineering Report for Envirite. The recovery data were transferred from the Onsite Engineering Report for Horsehead Resource Development Co. for K061. The correction of the analytical data and the correction factors used are presented in Table 7-3.

7.3 Calculation of Variability Factors

The variability factor represents the variability inherent in the treatment process and the sampling and analytical methods. Variability factors are calculated based on the treatment data for each of the regulated constituents. The general methodology for calculating variablity factors is presented in Appendix A. In cases where all of the treated values for a constituent are below the detection limits, a detection limit of 2.8 was used. The methodology used to calculate this variability factor is presented in Appendix A. The variability factors calculated for the regulated constituents for K001 are presented in Table 7-4. Appendix E of this report presents these calculations in detail.

7.4 Calculation of Treatment Standards

The treatment standards for the proposed regulated constituents were calculated by multiplying the average accuracy-corrected values by the appropriate variability factor. The treatment standards for BDAT are presented in Table 7-4.

Table 7-1 Corrected Values for BDAT List Organics

BDAT list constituent	Uncorrected detection limit (ppm)	Correction factor	Accuracy-corrected value
Naphthalene (ash)	<2.5	1.14	2.85
Naphthalene (water)	<0.050	1.06	0.053
Pentachlorophenol (ash)	<12.5	1.05	13.125
Pentachlorophenol (water)	<0.250	1.25	0.313
Phenanthrene (ash)	<2.5	1.04	2.60
Phenanthrene (water)	<0.050	1.06	0.053
Pyrene (ash)	<2.5	1.04	2.60
Pyrene (water)	<0.050	1.00	0.050
Toluene (ash)	<0.050	1.01	0.051
Toluene (water)	<0.050	1.01	0.051
Xylenes (ash)	<0.050	1.16	0.058
Xylenes (water)	<0.050	1.15	0.058

Table 7-2 Corrected Values for K001 Nonwastewater Regulated Metal Constituents
Treated by Stabilization

onstituent	Accuracy-corrected concentration (ppm)									Average (mg/l)
	Sample Set #									
	1	2	3	4	5	6	7	8	9	
BDAT metals										
Lead	--	0.39	--	--	--	0.39	0.41	0.40	0.29	0.375

Table 7-3 Corrected Values for K001 Wastewater Regulated Metal Constituents Treated by Chemical Precipitation and Filtration

		Accuracy-corrected concentration (mg/l)											
		Sample Set #											
Constituent	Correction factor	1	2	3	4	5	6	7	8	9	10	11	Average (mg/l)
BDAT metals													
Lead	1.32	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	0.013

Table 7-4 Calculation of Treatment Standards for K001

Regulated constituent	Average treated concentration (mg/kg, mg/l)	Variability factor (VF)	Treatment standard (VF x average)
Naphthalene (ash)	2.85	2.8	8.0
Naphthalene (water)	0.053	2.8	0.15
Pentachlorophenol (ash)	13.13	2.8	37
Pentachlorophenol (water)	0.313	2.8	0.88
Phenanthrene (ash)	2.85	2.8	8.0
Phenanthrene (water)	0.053	2.8	0.15
Pyrene (ash)	2.60	2.8	7.3
Pyrene (water)	0.050	2.8	0.14
Toluene (ash)	0.051	2.8	0.14
Toluene (water)	0.051	2.8	0.14
Xylenes (ash)	0.058	2.8	0.16
Xylenes (water)	0.058	2.8	0.16
Lead (nonwastewater)	0.375	1.37	0.51
Lead (wastewater)	0.013	2.8	0.037

8. ACKNOWLEDGMENTS

This document was prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract No. 68-01-7053. Mr. James Berlow, Chief, Treatment Technology Section, Waste Treatment Branch, served as the EPA Program Manager during the preparation of this document and the development of treatment standards for the K001 waste. The technical project officer for the waste was Ms. Lisa Jones. Mr. Steven Silverman served as legal advisor.

Versar personnel involved with preparing this document included Mr. Jerome Strauss, Program Manager; Mr. David Bottimore, Engineering Team Leader; Ms. Justine Alchowiak, Quality Assurance Officer; Mr. David Pepson, Senior Technical Reviewer; Ms. Juliet Crumrine, Technical Editor; and the Versar secretarial staff, Ms. Linda Gardiner and Ms. Mary Burton.

The K001 treatment tests were executed at the U.S. EPA Combustion Research Facility, Jefferson, Arkansas, by Acurex Corporation and at the John Zinc Test Facility, Tulsa, Oklahoma, by PEI Associates, contractors to the Office of Research and Development. Field sampling for the tests was conducted under the leadership of Mr. Ronald J. Turner and Ms. Mary Ann Curran of the EPA Office of Research and Development and Mr. Fred Hall of PEI Associates.

We greatly appreciate the cooperation of Allied Chemicals, Birmingham, Alabama, whose plants were sampled for the K001 wastes incinerated at the test facilities.

9. REFERENCES

Ackerman, D.G., McGaughey, J.F., and Wagoner D.E. 1983. At sea incineration of PCB-containing wastes on board the M/T Vulcanus, EPA 600/7-83-024. Washington, D.C.: U.S. Environmental Protection Agency.

Acurex Corporation. 1982. Emissions and residue values from waste disposal during wood preserving. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar, Inc. under Contract no. 68-01-7053, Work Assignment No. 38, April 1986.

Ajax Floor Products Corp. n.d. Product literature: technical data sheets on Hazardous Waste Disposal System. P.O. Box 161, Great Meadows, N.J. 07838.

Aldrich, J.R. 1985. Effects of pH and proportioning of ferrous and sulfide reduction chemicals on electroplating waste treatment sludge production. In Proceeding of the 39th Purdue Industrial Waste Conference, May 8-10, 1984. Stoneham, Mass: Butterworth Publishers.

Austin, G.T. 1984. Shreve's chemical process industries, 5th ed. New York: McGraw-Hill.

Bishop, P.L., Ransom, S.B., and Grass, D.L. 1983. Fixation mechanisms in solidification/stabilization of inorganic hazardous wastes. In Proceedings of the 38th Industrial Waste Conference, May 10-12, 1983, at Purdue University, West Lafayette, Indiana.

Bonner, T.A., et al. 1981. Engineering handbook for hazardous waste incineration. SW-889. NTIS PB 81-248163. Prepared by Monsanto Research Corporation under Contract no. 68-03-3025 for U.S. Environmental Protection Agency.

Castaldini, C., et al. 1986. Disposal of hazardous wastes in industrial boilers on furnaces, New Jersey: Noyes Publications.

Cherry, K.F. 1982. Plating waste treatment. pp. 45-67. Ann Arbor, Mich: Ann Arbor Science, Inc.

Conner, J.R. 1986. Fixation and solidification of wastes. Chemical Engineering. Nov. 10, 1986.

Cullinane, M.J., Jr., Jones, L.W., and Malone, P.G. 1986. Handbook for stabilization/solidification of hazardous waste. U.S. Army Engineer Waterways Experiment Station. EPA report no. 540/2-86/001. Cincinnati, Ohio: U.S. Environmental Protection Agency.

Cushnie, George C., Jr. 1985. Electroplating wastewater pollution control technology. pp. 48-62, 84-90. Park Ridge, N.J.: Noyes Publications.

Cushnie, George C., Jr. 1984. Removal of metals from wastewater: neutralization and precipitation. pp. 55-97. Park Ridge, N.J.: Noyes Publications.

CWM. 1987. Chemical Waste Management. Technical Report 87-117, Stabilization treatment of selected metal containing wastes. September 22, 1987. Chemical Waste Management, 150 West 137th Street, Riverdale, Ill.

DPRA. 1984. Data from OSW Mail Survey: Generator Questionnaire, Incinerator Questionnaire, Land Disposal Questionnaire. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment no. 38, April 1986.

Eckenfelder, W.W. 1985. Wastewater treatment. Chemical Engineering 85:72.

Electric Power Research Institute. 1980. FGD sludge disposal manual, 2nd ed. Prepared by Michael Baker, Jr., Inc. EPRI CS-1515 Project 1685-1. Palo Alto, Calif.: Electric Power Research Institute.

Grain, R.W. 1981. Solids removal and concentration. In Third Conference on Advanced Pollution Control for the Metal Finishing Industry. pp. 56-62. Cincinnati, Ohio: U.S. Environmental Protection Agency.

Gurnham, C.F. 1955. Principles of industrial waste treatment. pp. 224-234. New York: John Wiley and Sons.

Illinois Environmental Protection Agency. 1983. Special waste authorization file. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment no. 38, April 1986.

Kirk-Othmer. 1980. Encyclopedia of chemical technology, 3rd ed. Flocculation, Vol. 10. pp. 489-516. New York: John Wiley and Sons.

K.W. Brown and Associates, 1981. Hazardous waste land treatment. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment No. 38, April 1986.

Lanouette, K.H. 1977. Heavy metals removal. Chemical Engineering, October 17, 1977, pp. 73-80.

Mishuck, E., Taylor, D.R., Telles, R., and Lubowitz, H. 1984. Encapsulation/Fixation (E/F) mechanisms. Report no. DRXTH-TE-CR-84298. Prepared by S-Cubed under Contract no. DAAK11-81-C-0164.

Mitre Corporation. 1981. Composition of hazardous waste streams. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment no. 38, April 1986.

Mitre Corporation. 1983. Guidance manual for hazardous waste incinerator permits. NTIS PB84-100577. July 1983.

Myers, L.H., et al. 1979. Indicatory fate study. EPA OGC2-78-179. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment no. 38, April 1986.

Novak, R.G., Troxler, W.L., Dehnke, T.H. 1984. Recovering energy from hazardous waste incineration. Chemical Engineering Progress 91:146.

Oppelt, E.T. Incineration of hazardous waste. JAPCA 37(5).

Patterson, J.W. 1985. Industrial wastewater treatment technology, 2nd ed. Stoneham, Mass.: Butterworth Publishers.

Perry, R.H. and Chilton, C.H. 1973. Chemical engineers' handbook. 5th ed. Section 19. New York: McGraw Hill, Inc.

Pojasek, R.B. 1979. Solid-waste disposal: solidification. Chemical Engineering 86(17):141-145.

Rudolfs, W. 1953. Industrial wastes: their disposal and treatment. p. 294. Valley Stream, N.Y.: L.E.C. Publishers Inc.

Santoleri, J.J. 1983. Energy recovery--a by-product of hazardous waste incineration systems. In Proceedings of the 15th Mid-Atlantic Industrial Waste Conference on Toxic and Hazardous Waste.

U.S. Department of Commerce. 1984. 1982 census of manufacturers-miscellaneous chemical products. December 1984.

USEPA. 1978. Handbook of industrial waste compositions in California. 1978. Cited by Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, by Versar Inc. under Contract no. 68-01-7053, Work Assignment no. 38, April 1986.

USEPA. 1980a. U.S. Environmental Protection Agency, Office of Solid Waste. RCRA listing background document for waste code K001. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1980b. U.S. Environmental Protection Agency. U.S. Army Engineer Waterways Experiment Station. Guide to the disposal of chemically stabilized and solidified waste. Prepared for HWERL/ORD under Interagency Agreement No. EPA-IAG-D4-0569. PB81-181505. Cincinnati, Ohio: U.S. Environmental Protection Agency.

USEPA. 1983. U.S. Environmental Protection Agency. Treatability manual, Volume III, Technology for control/removal of pollutants. EPA-600/2-82-001C. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1985. U.S. Environmental Protection Agency, Waste Identification Branch, Characterization and Assessment Division. Characterization of waste streams listed in 40 CFR; Section 261, Waste Profiles. Prepared by Environ Corporation. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986a. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for Envirite Corporation, York, Pennsylvania. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986b. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Test methods for evaluating solid waste: physical/chemical methods, SW-846. 3rd ed. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986c. U.S. Environmental Protection Agency. Hazardous waste management systems; land disposal restrictions; final rule: Appendix I to Part 268 - Toxicity Characteristic Leaching Procedure (TCLP). 51 FR 40643-54, November 7, 1986.

USEPA. 1987a. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report for K001 - creosote. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1987b. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite Engineering Report for K001 - PCP. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report for Horsehead Resource Development Co., Inc. Palmerton, Pennsylvania, for K061. Washington, D.C.: U.S. Environmental Protection Agency.

Versar Inc. 1984. Estimating PMN incineration results. U.S. Environmental Protection Agency, Exposure Evaluation Division, Office of Toxic Substances. EPA Contract no. 68-01-6271, Task no. 66. Washington, D.C.: U.S. Environmental Protection Agency.

Vogel, G, et al. 1986. Incineration and cement kiln capacity for hazardous waste treatment. In Proceedings of the 12th Annual Research Symposium on Incineration and Treatment of Hazardous Wastes. April 1986, Cincinnati, Ohio.

APPENDIX A

STATISTICAL METHODS

A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

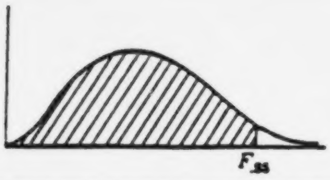
If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

95th PERCENTILE VALUES FOR THE F DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)



n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

where:

$x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and
$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

Steam stripping				Biological treatment			
Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-	-	23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10,\ n_2 = 5,\ N = 15,\ k = 2,\ T_1 = 23.18,\ T_2 = 12.46,\ T = 35.64,\ T^2 = 1270.21$

$T_1^2 = 537.31 \quad T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

$MSB = 0.10/1 = 0.10$

$MSW = 0.77/13 = 0.06$

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

	Steam stripping				Biological treatment		
Influent (μg/l)	Effluent (μg/l)	ln(effluent)	[ln(effluent)]^2	Influent (μg/l)	Effluent (μg/l)	ln(effluent)	[ln(effluent)]^2
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum:							
-	-	26.14	72.92	-	-	16.59	39.52
Sample Size:							
10	10	10	-	7	7	7	-
Mean:							
2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:							
3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:							
-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$MSB = SSB/(k-1)$

$MSW = SSW/(N-k)$

Example 2 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7}\right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

$MSB = 0.25/1 = 0.25$

$MSW = 4.79/15 = 0.32$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$\ln[(\text{effluent})]^2$
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	-
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^{2}}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$MSB = SSB/(k-1)$

$MSW = SSW/(N-k)$

$F = MSB/MSW$

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4$, $N_2 = 7$, $N = 11$, $k = 2$, $T_1 = 14.49$, $T_2 = 38.90$, $T = 53.39$, $T^2 = 2850.49$, $T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left(\frac{209.96}{4} + \frac{1513.21}{7}\right) - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left(\frac{209.96}{4} + \frac{1513.21}{7}\right) = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{Mean}$$

where:

VF = estimate of daily maximum variability factor determined from a sample population of daily data;

C_{99} = estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = Exp(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data; and

Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{Mean}. \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \mathrm{Exp}\ (\mu + 2.33\sigma) \qquad (2)$$
$$Mean = \mathrm{Exp}\ (\mu + 0.5\sigma^2). \qquad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \mathrm{Exp}\ (2.33\ \sigma - 0.5\sigma^2). \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

  $$\sigma = [\ln(UL) - \ln(LL)] / [(2)(2.33)]$$
  $$= [\ln(UL/LL)] / 4.66. \qquad (5)$$

  (Note that when $LL = (0.1)(UL)$ as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494.$)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

  $$\begin{aligned}\sigma &= [\ln(UL) - \ln(LL)] / [(2)(2.33)] \\ &= [\ln(UL/LL)] / 4.66. \qquad (5)\end{aligned}$$

  (Note that when $LL = (0.1)(UL)$ as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494.$)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

APPENDIX B

ANALYTICAL METHODS AND QA/QC

This appendix presents the analytical methods and the matrix spike recoveries for the K001 samples. Matrix spike recoveries are also presented for other waste samples used to develop treatment standards for K001 waste.

B-1 Analytical Methods for K001 Regulated Organic Constituents

Regulated constituent	Extraction method	method number	Analytical method/method no.	
Volatile Organics				
Toluene	Purge and trap	5030	GC/MS	8240
Xylenes (total)	Purge and trap	5030	GC/MS	8240
Semivolatile Organics				
Naphthalene	Continuous Liquid/ Extraction	3580	GC/MS	8270
Pentachlorophenol	Continuous Liquid/ Extraction	3580	GC/MS	8270
Phenanthrene	Continuous Liquid/ Extraction	3580	GC/MS	8270
Pyrene	Continuous Liquid/ Extraction	3580	GC/MS	8270

Reference: USEPA. 1986. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Test methods for evaluating solid waste, SW 846. 3rd ed. Washington, D.C.: U.S. Environmental Protection Agency.

Table B-2 K001 - Matrix Spike Recoveries Used to Calculate Correction Factors for Regulated Organic Constituents

Regulated constituent	Percent recovery: Sample	Percent recovery: Duplicate	Correction factor used
Volatile Organics			
Toluene (ash)	99	110	1.01
Toluene (water)	103	99	1.01
Xylenes (ash)	86.4 (average)	96.4 (average)	1.16
Xylenes (water)	100 (average)	94 (average)	1.15
Semivolatile Organics			
Naphthalene (ash)	88 (average)	93 (average)	1.14
Naphthalene (water)	94 (average)	96 (average)	1.06
Pentachlorophenol (ash)	95	105	1.05
Pentachlorophenol (water)	80	0	1.25
Phenanthrene (ash)	88 (average)	93 (average)	1.14
Phenanthrene (water)	94 (average)	96 (average)	1.06
Pyrene (ash)	96	100	1.04
Pyrene (water)	110	110	1.00

Reference: Onsite Engineering Report for K001-Creosote (USEPA 1987a).

Table B-3 K001 Creosote Water Sample Volatile Organics
Matrix Spike Recoveries (%)

	Spike level (ug/l)	#1	#2	RPD
1,1-Dichloroethene	25	100	97	3.0
Toluene	25	103	99	4.0
Chlorobenzene	25	95	90	5.4
Benzene	25	90	85	5.7
Trichloroethylene	25	69	64	7.5

Reference: Onsite Engineering Report for K001-Creosote (USEPA 1987a).

Table B 4 K001 Creosote Ash Sample Volatile Organics Matrix Spike Recoveries (%)

	Spike level (ug/l)	#1	#2	RPD
1,1-Dichloroethene	25	86	95	9.9
Toluene	25	99	110	10
Chlorobenzene	25	102	112	9.3
Benzene	25	78	88	12
Trichloroethylene	25	67	77	14

Reference: Onsite Engineering Report for K001-Creosote (USEPA 1987a).

Table B-5 K001 Creosote Water Sample Semivolatile Organic Matrix Spike Recoveries (%)

Compound	Initial conc. (ug/l)	Amount added (ug/l)	% Recovery		RPD
			#1	#2	
Phenol	<10	100	65	61	6
2-Chlorophenol	<10	100	61	65	6
1,4-Dichlorobenzene	<10	50	61	51	16
N-nitroso-di-n-propylamine	<100	50	70	56	20
1,2,4 Trichlorobenzene	<10	50	72	54	25
4-Chloro-3-methylphenol	<10	100	80	73	9
Acenaphthene	<10	50	81	66	19
4-Nitrophenol	<50	100	0	0	NC
2,4-Dinitrotoluene	<10	50	21	17	19
Pentachlorophenol	<50	100	80	85	6
Pyrene	<10	50	62	60	3

NC - Not calculated.

Reference: Onsite Engineering Report for K001-Creosote (USEPA 1987a).

Table B-6 K001 Creosote Ash Sample Semivolatile Organics Matrix Spike Recoveries (%)

Compound	Initial conc. (ug/g)	Amount added (ug/g)	% Recovery #1	#2	RPD
Phenol	<4	67	72	65	9.7
2-Chlorophenol	<4	67	59	53	10
1,4-Dichlorobenzene	<4	33	48	46	4.2
N-nitroso-di-n-propylamine	<4	33	67	62	7.5
1,2,4-Trichlorobenzene	<4	33	30	30	0
4-Chloro-3-methylphenol	<4	67	35	68	48
Acenaphthene	<4	33	0	3.4	100
4-Nitrophenol	<20	67	1.2	2.6	54
2,4-Dinitrotoluene	<4	33	0	0	NC
Pentachlorophenol	<20	67	0	0	NC
Pyrene	<4	33	0	0	NC

NC - Not calculated.

Reference: Onsite Engineering Report for K001-Creosote (USEPA 1987a).

Table B-7 K001-PCP Ash Duplicate Matrix Spike Data, Volatile Organic Analyses

Compound	Original amount present, µg/liter	Amount spiked, µg/liter	Amount recovered, mg/l liter		% Recovery	
			No. 1	No. 2	No. 1	No. 2
Toluene	3	25	30	30	108	108
Chlorobenzene	<2	25	31	30	124	120
Benzene	<2	25	22	22	88	88
Trichloroethene	<2	25	22	21	88	84

Reference: Onsite Engineering Report for K001 Pentachlorophenol (USEPA 1987b).

Table B-8 K001-PCP TCLP Ash Duplicate Matrix Spike Data, Volatile Organic Analyses

Compound	Original amount present, µg/liter	Amount spiked, µg/liter	Amount recovered, mg/l liter		% Recovery	
			No. 1	No. 2	No. 1	No. 2
1,1 Dichloroethylene	<2	25	23	28	92	112
Toluene	<2	25	30	30	120	120
Chlorobenzene	<2	25	30	26	120	104
Benzene	<2	25	23	30	92	120
Trichloroethene	<2	25	21	21	84	84

Reference: Onsite Engineering Report for K001 Pentachlorophenol (USEPA 1987b).

Table B-9 K001-PCP TCLP Ash Duplicate Matrix Spike Data, Semivolatile Organic Analyses

Compound	Initial concentration, µg/liter	Amount added, µg/liter	Amount recovered, mg/l liter		% Recovery	
			No. 1	No. 2	No. 1	No. 2
Phenol	2	10,000	10,000	10,000	100	100
2-Chlorophenol	<2	10,000	10,000	11,000	100	110
1,4-Dichlorobenzene	<2	5,000	5,500	5,500	110	110
N-Nitrosodinipropylamine	<5	5,000	6,500	7,000	130	140
1,2,4-Trichlorobenzene	<5	5,000	4,700	4,600	94	92
4-Chloro-3-methylphenol	<5	10,000	8,000	9,000	80	90
Acenaphthene	14,000	5,000	20,000	20,000	120	120
4-Nitrophenol	<10	10,000	8,400	7,500	84	75
2,4-Dinitrotoluene	<50	5,000	6,000	6,000	120	120
Pentachlorophenol	<50	10,000	10,000	10,000	100	100
Pyrene	11,000	5,000	15,000	16,000	80	100

Reference: Onsite Engineering Report for K001-Pentachlorophenol (USEPA 1987b).

Table B-10 K001-PCP TCLP Ash Duplicate Matrix Spike Data, Volatile Organic Analyses

Compound	Initial concen-tration, µg/liter	Amount added, µg/liter	Amount recovered, mg/l liter No. 1	Amount recovered, mg/l liter No. 2	% Recovery No. 1	% Recovery No. 2
Phenol	2	200	170	160	85	80
2-Chlorophenol	<2	200	200	210	100	105
1,4-Dichlorobenzene	<2	100	94	94	94	94
N-Nitrosodinipropyl amine	<5	100	81	82	81	82
1,2,4-Trichlorobenzene	<5	100	95	100	95	100
4-Chloro-3-methylphenol	<5	200	180	190	90	95
Acenaphthene	<5	100	120	120	120	120
4-Nitrophenol	<10	200	200	180	100	90
2,4-Dinitrotoluene	<50	100	120	120	120	120
Pentachlorophenol	<50	200	190	210	95	105
Pyrene	<2	100	96	100	96	100

Reference: Onsite Engineering Report for K001-Pentachlorophenol (USEPA 1987b).

Table B-11 K001-PCP Scrubber Water Duplicate Matrix Spike Data
Semivolatile Organic Analyses

Compound	Initial concentration, µg/liter	Amount added, µg/liter	Amount recovered, mg/l liter		% Recovery	
			No. 1	No. 2	No. 1	No. 2
Phenol	<2	200	60	45	30	22
2 Chlorophenol	<2	200	56	40	28	20
1,4-Dichlorobenzene	<2	100	85	87	85	87
N-Nitrosodinipropylamine	<5	100	70	66	70	66
1,2,4 Trichlorobenzene	<5	100	110	120	110	120
4-Chloro-3-methylphenol	<5	200	58	44	29	22
Acenaphthene	<5	100	110	110	110	110
4-Nitrophenol	<10	200	3	1.5	1.5	0.8
2,4-Dinitrotoluene	<50	100	79	84	79	84
Pentachlorophenol	<50	200	6	3.4	3	1.7
Pyrene	<2	100	110	110	110	110

Reference: Onsite Engineering Report for K001-Pentachlorophenol (USEPA 1987b).

Table B-12 Matrix Spike Recoveries for Stabilized F006 Nonwastewater Residuals

Constituent	Original amount found (ppm)	Duplicate (ppm)	% Error	Actual Spike	% Recovery	Accuracy correction factor[a]
Lead	0.3226	0.3091	2.14	4.9619	92.9	1.08
	0.2142	0.2287	3.27	4.6930	89.4	1.12

[a] Accuracy correction factor = 100 ÷ percent recovery.

Reference: Memo to R. Turner, USEPA/HWERL, from Jesse R. Conner, Chemical Waste Management, dated January 20, 1988.

Table B 13 Matrix Spike Recovery for Metals for the TCLP Extract for K061
for Horsehead Resource Development Co.

		Sample set 4			Sample set duplicate 4		
BDAT constituent	Original sample (ug/l)	Spike added (ug/l)	Spike result (ug/l)	Percent recovery[a]	Spike result (ug/l)	Percent recovery[a]	Correction factor
Lead	<5.0	25	22	88	19	76	1.32

[a] Percent recovery = [(spike result - original amount)/spike amount] x 100%.

[b] RPD = [(S1-S2)/(S1+S2)/2)] x 100, where S1 is the larger of the percent recoveries.

Reference: Onsite Engineering Report for Horsehead Resource Development Co. (USEPA 1988).

APPENDIX C

CONCENTRATION/BOILING POINT/BOND DISSOCIATION ENERGY RANKING FOR BDAT LIST VOLATILES/SEMIVOLATILES IN K001

The methodology used by the Agency to select regulated constituents for K001 volatiles and semivolatiles is based on WCAPs for rotary kiln incineration; namely, the concentration, boiling point, and bond dissociation energies. Table C-1 presents these values.

Table C-1 Concentration/Boiling Point/Bond Dissociation Energy Ranking for BDAT List Volatiles/Semivolatiles in K001

	Concentration			Boiling Point (°C)			Bond Dissociation Energy (Kcal/mol)	
	Volatiles (ppb)			Volatiles			Volatiles	
1.	Xylenes	120-170	1.	Xylenes	140	1.	Xylenes	1,905
2.	Toluene	10-170	2.	Ethylbenzene	136	2.	Ethylbenzene	1,905
3.	Ethylbenzene	55-87	3.	Toluene	111	3.	Toluene	1,620
4.	Benzene	51 83	4.	Benzene	80	4.	Benzene	1,335

	Semivolatiles (ppm)			Boiling point (°C)			Bond Dissociation Energy (Kcal/mol)	
1.	Naphthalene	26,000-43,000	1.	Benzo(b/k) fluoranthrene	480	1.	Benzo(b/k fluoranthrene	4,140
2.	Phenanthrene	28,000-42,000	2.	Chrysene	448	2.	Benzo(c)pyrene	4,030
3.	Acenaphthalene	13,000 21,000	3.	Benz(a)anthracene	435	3.	Chrysene	3,775
4.	Fluoranthene	13,000-21,000	4.	Pyrene	404	4.	Benz(a)anthracene	3,680
5.	Fluorene	8,200-18,000	5.	Fluoranthene	375	5.	Pyrene	3,240
6.	Pyrene	12,000-17,000	6.	Anthrecene	342	6.	Fluoranthene	3,130
7.	Anthracene	7,300-15,000	7.	Phenanthrene	340	7.	Phenanthrene	2,900
8.	Chrysene	2,500-4,800	8.	Benzo(a)pyrene	311	8.	Fluorene	2,725
9.	Phenol	2,400-3,900	9.	Pentachlorophenol	309	9.	Anthracene	2,715
10.	Benz(a)anthracene	2,500-3,400	10.	Fluorene	295	10.	Acenaphene	2,570
11.	Pentachlorophenol	920-3,000	11.	Acenaphthene	279	11.	Naphthalene	2,025
12.	Benzo(b/k) fluoranthrene	940-2,300	12.	Naphthalene	218	12.	Phenol	1,435
13.	Benzo(a)pyrene	250-940	13.	Phenol	182	13.	Pentachlorophenol	1,410

APPENDIX D

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded. Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure D-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed in a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

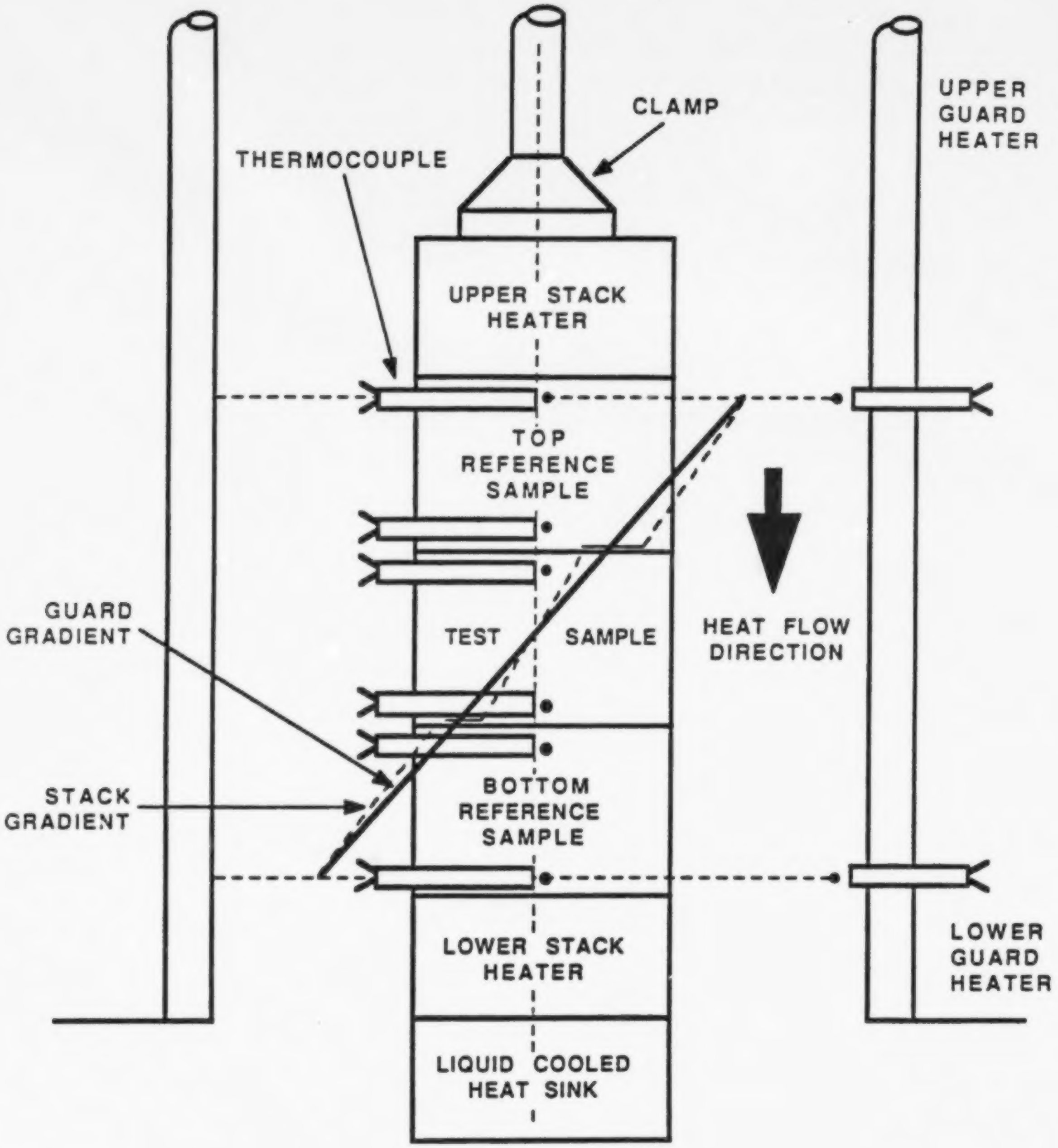

UPPER GUARD HEATER
CLAMP
THERMOCOUPLE
UPPER STACK HEATER
TOP REFERENCE SAMPLE
HEAT FLOW DIRECTION
GUARD GRADIENT
TEST SAMPLE
STACK GRADIENT
BOTTOM REFERENCE SAMPLE
LOWER STACK HEATER
LOWER GUARD HEATER
LIQUID COOLED HEAT SINK

FIGURE D-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The stack is clamped with a reproducible load to ensure intimate contact between the components. To produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack, and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady-state method of measuring thermal conductivity. When equilibrium is reached, the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top} (dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom} (dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference, while bottom refers to the lower reference. If the heat were confined to flow down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2.$$

The sample thermal conductivity is then found from

$$\lambda_{sample} = Q(dT/dx)_{sample}.$$

APPENDIX E

CALCULATIONS OF TREATMENT STANDARDS

The following pages show calculations of treatment standards for the regulated constituents in K001 waste.

CALCULATIONS OF TREATMENT STANDARDS

K001 Volatiles

---

1. Toluene

	Ash	Water	Use
Detection limits			
Creosote OER	<50	<50	0.050 ppm
PCP OER	<10	<10	
Recovery for creosote	99	99	
Recovery for PCP	100	100	

CF = 1.01
CF = 1.01
Avg = 0.051
VF = 2.8
Toulene standard ash = 0.143
Toulene standard water = 0.143

2. Xylene

	Ash	Water	Use
Detection limits			
Creosote OER	<50	<50	<0.050 ppm
PCP OER	<10	<10	
Recovery for creosote	86.4	87	
Recovery for PCP	94	93.6	

CF = 1.16 (ash)
CF = 1.15 (water)
VF = 2.8
Xylene standard ash = 0.162
Xylene standard water = 0.161

Standards rounded off:

Toluene (ash)	0.14 mg/kg
Toluene (water)	0.14 mg/l
Xylene (ash)	0.16 mg/kg
Xylene (water)	0.16 mg/l

K001 Semivolatiles

---

3. **Naphthalene**

	Ash	Water	Use
Detection limits			
Creosote OER	<0.55	<0.010	<2.5 ash
PCP OER	<2.5	<0.050	<0.050 water
Recovery for Napthalene			
Cresote	88	57.4	
PCP	88	94	

CF = 1.19 (ash)
CF = 1.06 (PCP)
VF - 2.8
Naphthalene standard ash = 7.98
Naphthalene standard water = 0.148

4. **Phenanthrene**

	Ash	Water	Use
Detection limits			
Creosote OER	<1.8	<0.030	<2.5 ash
PCP OER	<2.5	<0.050	<0.050 water
Recovery for Phenanthrene			
Creosote	88	57.4	
PCP	88	94	

CF = 1.14 (ash)
CF = 1.06 (PCP)
VF = 2.8
Phenanthrene standard ash = 7.98
Phenanthrene standard water = 0.148

Standards rounded off:

Naphthalene (ash)	8.0 mg/kg
Naphthalene (water)	0.15 mg/l
Phenanthrene (ash)	8.0 mg/kg
Phenanthrene (water)	0.15 mg/l

K001 Semivolatiles

---

5. Pentachlorophenol

	Ash	Water	Use
Detection limits			
Creosote OER			<12.5 ash
PCP OER	<12.5	<0.0250	<0.250 water
Recovery for Pentachlorophenol			
Creosote	95	3,1.7[a]	
PCP	88	80	

CF = 1.05 (ash)
CF = 1.25 (PCP)
VF = 2.8
Pentachlorophenol standard ash = 36.75
Pentachlorophenol standard water = 0.875

6. Pyrene

	Ash	Water	Use
Detection limits			
Creosote OER	<0.65	<0.010	<2.5 ash
PCP OER	<2.5	<0.050	<0.050 water
Recovery for Pyrene			
Creosote	0	60	
PCP	96	110	

CF = 1.04 (ash)
CF = 1.06 (PCP)
VF = 2.8
Pyrene standard ash = 7.20
Pyrene standard water = 0.140

Standards rounded off:

Pentachlorophenol (ash)	37 mg/kg
Pentachlorophenol (water)	0.88 mg/l
Pyrene (ash)	7.3 mg/kg
Pyrene (water)	0.14 mg/l

K001 Wastewaters Metals Data from Envirite

Lead

Corrected values	VF	Standard
<0.013	2.8 mg/l	0.037 mg/l
<0.013		
0.013		
0.013		
0.013		
0.013		
0.013		
0.013		
0.013		
0.013		
0.013		

Mean = 0.013

K001 Nonwastewaters Stabilization of Metals from F006 Data

Lead

Accuracy Corrected Values	Variability Factor	Standard
0.39	1.37	0.051 mg/l
-		
0.39		
0.41		
0.40		
0.29		
-		
-		

Mean - 0.375

APPENDIX F

DELETION OF PERFORMANCE DATA FOR F006 WASTES

Table F-1 shows the deletion of data ponts from F006 stabilization performance data.

Table F-1 Deletion of Stabilization Performance Data for F006 Wastes

Source	Mix Ratio[a]	Metal concentrations (ppm) Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Unknown												
Unstabilized												
As received		-	36.4	1.3	1270	40.2	35.5	-	435	-	2.3	1560
TCLP		<0.01	0.08	0.01	0.34	0.15	0.26	<0.001	0.71	<0.01	0.01	0.16
Stabilized												
TCLP	0.2	<0.01^{b}	0.122^{c}	0.011^{d}	0.587^{c}	0.206^{c}	0.336^{c}	<0.001^{b}	0.046	0.058^{b}	0.035^{d}	0.034
Autopart manufacturing												
Unstabilized												
As received		-	21.6	31.3	755	7030	409	-	989	-	6.62	4020
TCLP		<0.01	0.32	2.21	0.76	368	10.7	<0.001	22.7	<0.01	0.14	219
Stabilized												
TCLP	0.2	<0.01^{e}	0.51^{e}	0.53^{e}	0.46^{e}	5.56^{e}	0.448^{e}	<0.001^{e}	1.73^{e}	0.058^{e}	0.035^{e}	42.1^{e}
TCLP	0.5	<0.01^{b}	0.458^{c}	0.010	0.454	0.27	0.389	<0.001^{b}	0.033	0.118^{b}	0.059	0.010
Aircraft overhauling												
Unstabilized												
As received		-	85.5	67.3	716	693	25.7	-	259	-	39	631
TCLP		0.01	1.41	1.13	0.43	1.33	0.26	<0.001	1.1	<0.01	0.02	5.41
Stabilized												
TCLP	0.2	<0.01^{b}	0.337	0.064	0.092	1.69^{c}	0.336^{c}	<0.001^{b}	0.265	0.067^{b}	0.236^{c}	0.057
TCLP	0.5	<0.01^{e}	0.338^{e}	0.020^{e}	0.234^{e}	1.99^{e}	0.443^{e}	<0.001^{e}	0.167^{e}	0.128^{e}	0.059^{e}	0.030^{e}
Aerospace manufacturing (F006 & F007 mixture)[f]												
Unstabilized												
As received		-	0.74	1.69	12.9	18.6	11.4		234		6.26	8.86
TCLP		<0.01	0.83	0.66	7.58	4.12	6.86	0.003	158	<0.01	1.64	2.28
Stabilized												
TCLP	1.0	<0.01	0.530	<0.01	0.46	0.237	0.224	<0.001	5.00	0.16	0.106	0.057
TCLP	1.5	<0.01	1.29	0.010	0.398	0.205	0.389	<0.001	2.74	0.232	0.177	0.030

Table F 1 (Continued)

Source	Mix Ratio[a]	Metal concentrations (ppm)										
		Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Zinc plating												
Unstabilized												
As received		-	17.2	1.30	110	1510	88.5		37	-	9.05	90200
TCLP		-	0.84	0.22	0.18	4.6	0.45	<0.001	0.52	-	0.16	2030
Stabilized												
TCLP	0.2	<0.01^{e}	0.204^{e}	0.011^{e}	0.263^{e}	0.309^{e}	0.336^{e}	<0.001^{e}	0.115^{e}	0.077^{e}	0.035^{e}	06.5^{e}
TCLP	0.5	<0.01^{b}	0.251	0.010	0.351^{c}	0.206	0.367^{g}	<0.001^{b}	0.022	0.162^{b}	0.047	0.004
Unknown												
Unstabilized												
As received		-	14.3	720	12200	160	52	-	701	-	5.28	35900
TCLP		<0.01	0.38	23.6	25.3	1.14	0.45	<0.001	9.78	<0.01	0.08	867
Stdbilized												
TCLP	0.2	<0.01^{e}	0.316^{e}	3.424^{e}	0.288^{e}	0.206^{e}	0.269^{e}	<0.001^{e}	0.610^{e}	0.034^{e}	0.047^{e}	3.88^{e}
TCLP	0.5	<0.01^{b}	0.207	0.010	0.44	0.313	0.389^{g}	<0.001^{b}	0.046	0.104^{b}	0.071^{g}	0.030
Small engine manufacturing												
Unstabilized												
As received		-	24.5	7.28	3100	1220	113	-	19400	-	4.08	27800
TCLP		<0.01	0.07	0.3	38.7	31.7	3.37	0.003	730	<0.01	0.12	1200
Stabilized												
TCLP	0.2	<0.01^{e}	0.306^{e}	0.021^{e}	0.242^{e}	0.216^{e}	0.336^{e}	<0.001^{e}	18.9^{e}	0.048^{e}	0.035^{e}	41.4^{e}
TCLP	0.5	<0.01^{b}	0.360^{c}	0.010	0.889	0.206	0.389	<0.001^{b}	0.055	0.128^{b}	0.059	0.040
Circuit board manufacturing												
Unstabilized												
As received		-	12.6	5.39	42900	10600	156	-	13000	-	12.5	120
TCLP		<0.01	0.04	0.06	360	8.69	1.0	<0.001	152	<0.01	0.05	0.62
Stabilized												
TCLP	0.2	<0.01^{e}	0.041^{e}	0.011^{e}	3.45^{e}	0.412^{e}	0.336^{e}	<0.001^{e}	0.46^{e}	0.034^{e}	0.035^{e}	0.023^{e}
TCLP	0.5	<0.01^{b}	0.153^{c}	0.010	1.416	0.454	0.410	<0.001^{b}	0.111	0.031^{b}	0.059^{c}	0.020

Table F-1 (Continued)

Source	Mix Ratio[a]	Metal concentrations (ppm)										
		Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Unknown												
Unstabilized												
As received		-	15.3	5.81	47.9	17600	169		23700		8.11	15700
TCLP		<0.01	0.53	0.18	0.04	483	4.22	<0.001	644	<0.01	0.31	650
Stabilized												
TCLP	0.2	<0.01[e]	0.326[e]	0.011[e]	0.115[e]	0.515[e]	0.347[e]	<0.001[e]	18.1[e]	0.067[e]	0.035[e]	5.18[e]
TCLP	0.5	<0.01[b]	0.294	0.010	0.234[c]	0.346	0.400	<0.001[b]	0.044	0.081[b]	0.059	0.020
Unknown												
Unstabilized												
As received		-	19.2	5.04	644	27400	24500		5730	-	19.1	322
TCLP		0.88	0.28	0.01	0.01	16.9	50.2	<0.001	16.1	<0.45	<0.01	1.29
Stabilized												
TCLP	0.2	<0.02[e]	0.194[e]	<0.01[e]	0.035[e]	3.28[e]	2.677[e]	<0.001[e]	1.25[e]	<0.01[e]	<0.01[e]	0.080[e]
TCLP	0.5	<0.02[b]	0.087	<0.010[d]	0.256[d]	0.497	0.291	<0.001[b]	0.022	<0.01[b]	<0.01[d]	<0.01

[a] Mix ratio = $\frac{\text{weight of reagent}}{\text{weight of waste}}$

[b] Data deleted because no untreated total composition or TCLP value is available to demonstrate treatment.

[c] Data deleted because treated TCLP value is greater than untreated TCLP value.

[d] Data deleted because untreated TCLP value is too low to show meaningful treatment.

[e] Data deleted because of less effective design and operation.

[f] Data deleted because untreated waste is a mixture of F006 and F007.

[g] Data deleted because reduction in leachability is attributed to dilution rather than treatment.

Reference: Chemical Waste Management Report No. 87-117 (CWM 1987).